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# Sample Study Material
# CSIR-NET Earth Sciences

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# The Earth And The Solar System

## 1. MILKY WAY AND THE SOLAR SYSTEM

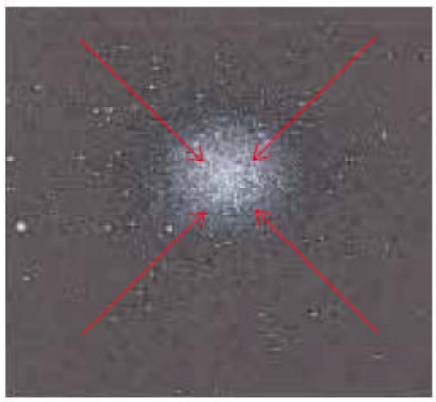
**The Solar system :** The solar system comprises the sun and its eight planets which are believed to have been originated from the condensation of gases and other lesser bodies. All planet of solar system revolve round the sun in Elliptical orbits. The sun form centre of solar system having surface temperature of 6,000 degree centrigrade. The temperature of sun increasing in interior up to 20 million degree centigrade.

**The Early solar system :** No one can go back in time to view the formation of the solar system and the Earth. Therefore, scientists will never be able to describe the sequence of events with certainty.

The hypothesis given here is based on calculations about the behavior of dust and gas in space and on observations of stars and dust clouds in our galaxy

The hypothesis states that about 5 billion years ago the matter that became our Solar system was an immense, diffuse, frozen cloud of dust and gas rotating slowly in space. This cloud formed from matter ejected from an exploding star. More than 99 percent of the cloud consisted of hydrogen and helium, the most abundant elements in the Universe. The temperature of this cloud was about 270ºC. Small gravitational attractions among the dust and gas particles caused the cloud to condense into a sphere (figure 1(a) and 1(b)). As condensation continued, the cloud rotated more rapidly, and the sphere spread into a disk, as shown in figure 1(c). Some scientist have suggested that a nearby star exploded and the shock wave triggered the condensation.

(a)



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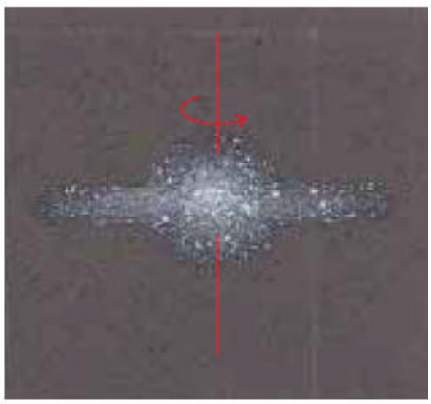

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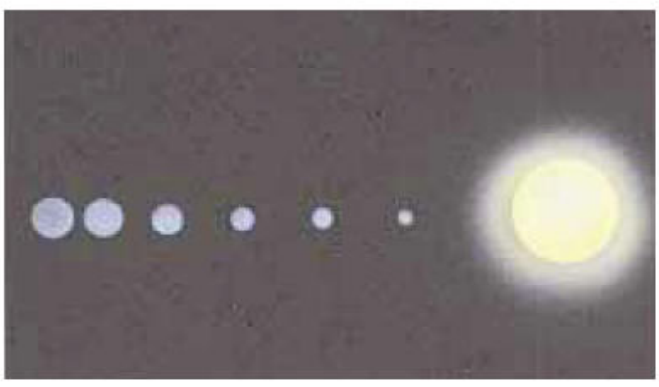

(e)

**Figure- 1 formation of the Solar System (a) Solar System was originally "a diffuse cloud dust and gas. (b) This dust and gas began to coalesce due to gravity. (c) The shrinking mass began to rotate and formed a disk. (d) The mass broke into a discrete protosun orbited by large "protoplanets. (e) The Sun heated until fusion temperatures were reached. The "heat from the Sun drove most of the hydrogen and helium away from the closest planets, leaving small, solid cores behind.**

More than 90 percent of the matter in the cloud collapsed toward the centre of the disk under the influence of gravity, forming the protosun. Collisions among high speed particles released heat within this early version of the Sun, but it was not a true star because it did not yet generate energy by nuclear fusion. Heat from the protosun warmed the inner region of the disk. Then, after the gravitational collapse was nearly complete, the disk cooled. Gases in the outer part of the disk condensed to form small aggregates, much as snowflakes form when moist air cools in the Earth's atmosphere. Over time, the aggregates stuck together as snowflakes sometimes do. As they increased in size and developed stronger gravitational forces, they attracted additional particles. This growth continued until a number of small rocky sphere, called planetesimals, formed, ranging from a few kilometers to about 100 km in diameter. The entire process, from the disk to the planetesimals, occurred quickly in geologic terms, over a period of 10,000 to 100,000 years. The planetesimals then coalesced to form a few large planets, including Earth. At the same time that planets were forming, gravitational attraction pulled the gases in the protosun inward, creating extremely high pressure and temperature.

The core became so hot that hydrogen nuclei combined to form the nucleus of the next heavier element, helium, in a process called nuclear fusion. Nuclear fusion releases vast amounts of energy. The onset of nuclear fusion marked the birth of the modern Sun, which still generates its energy by hydrogen fusion.

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## 2. THE MODERN SOLAR SYSTEM

Heat from the Sun boiled most of the hydrogen, helium and other light elements away from the inner solar system. As a result, the four planets closest to the Sun mercury, Venus, Earth and Mars- are now mainly rocky with metallic centers. These four are called the terrestrial planets because they are “Earthlike.” In contrast, the four outer planets- Jupiter, Saturn , Uranus, and Neptune- care called the Jovian planets and are composed primarily of liquids and gases with small rocky and metallic cores (figure 1.1). Pluto, the outermost known planet, is anomalous. It is the smallest planet in the Solar system and is composed of rock mixed with froze water and methane. Figure 1.2 is a schematic representation of the modern solar system.

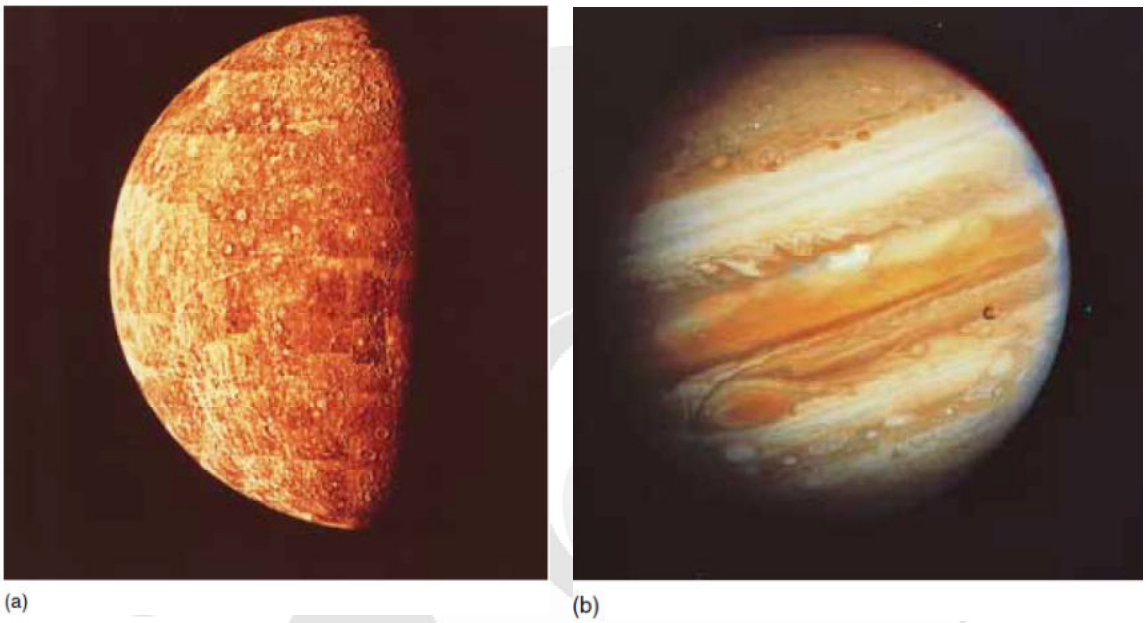


**Figure : 1.1 (a)** Mercury is a small planet close to the Sun. Consequently, most of the lighter elements have long since been boiled off into space, and today the surface is solid and rocky. **(b)** Jupiter, on the other hand, is composed mainly of gases and liquids, with a small solid core. This photograph shows its turbulent atmosphere. The scales in these two photographs are different. Jupiter is much larger than Mercury. (NASA)

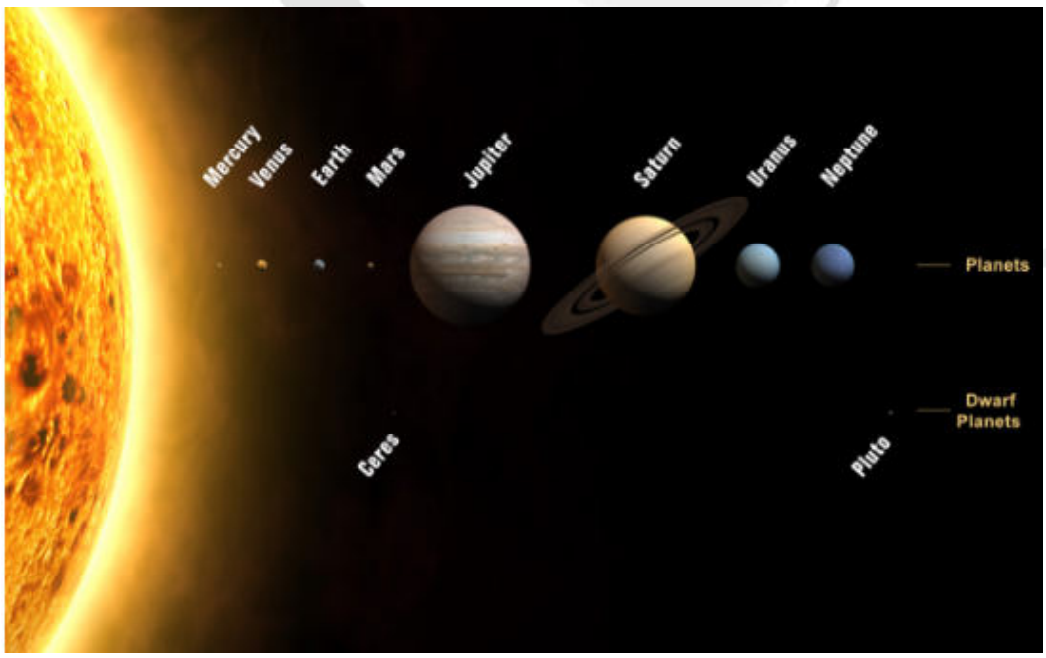


**Figure 1.2 : The Solar System. Now, Pluto is considered as dwarf planet.**

Among the eight planets, Mercury is the smallest and closest to the sun 36 million miles away. It completes its orbit in only 88 days. Venus, is next closest planet. It is similar to earth in terms of size, mass and density and therefore considered as 'Earth Twin'. Earth is unique planet in terms of existence of life and presence of water. Like many other planet of solar system, the earth has a natural satellite the moon, 382,480 km away, that revolves eastward around the earth once in every 27 days.

The fourth planet from the sun is Mars which has dark patches on its surface. Scientist is giving much attention on mars to explore the possibility of life. Next to this is Jupiter, the largest planet in the solar system. Its surface is made up of gases such as hydrogen, helium and methane. It has twelve satellites that circle around it. Its surface is very cold.

Next to it is a unique planet called Saturn having three rings and nine satellites around it. In terms of size it is next to Jupiter. It is quite far from sun and therefore it takes 29.5 years to complete its orbit.

The next planet of solar system after Saturn is Uranus. It is another giant planet, around fifty times larger than earth. Uranus is unique as it moves in a clockwise direction from east to west with five satellites revolving around it.

Neptune closely resemble with Uranus. It has only two satellites and colder surface. Pluto is now considered as dwarf planet and removed from the list of Planet by Astronomical Union.

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# 3. MODERN THEORIES ON THE ORIGIN OF THE EARTH AND OTHER PLANETARY BODIES

**The Big Bang Theory :**

The most popular argument regarding the origin of the universe is the Big Bang theory. It is also called expanding universe hypothesis. Edwin Hubble, in 1920, provided evidence that the universe is expanding. As time passes, galaxies move further and further apart. Experiment and find what does the expanding universe mean, the distance between the galaxies is found to be increasing and thereby, the universe is considered to be expanding. Scientists believe that though the space between the galaxies is increasing observations do not support the expansion of galaxies.

The Big Bang Theory considers the following stages in the development of the universe.

**(i)** In the beginning, all matter forming the universe existed in one place in the form of a "tiny ball" (singular atom) with an unimaginably small volume, infinite temperature and infinite density.

**(ii)** At the Big Bang the "tiny ball" exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event the first atom began to form.

**(iii)** Within 300,000 years from the Big Bang, temperature dropped to 4,500 K and gave rise to atomic matter. The universe became transparent. The expansion of universe means increases in space between the galaxies. An alternative to this was Hoyle's concept of steady state. It considered the universe to be roughly the same at any point of time. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe.

**Formation of Planets**

The following are considered to be the stages in the development of planets :

(i) The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core to the gas cloud and a huge rotating disc of gas and dust develops around the gas core.

(ii) In the next stage, the gas cloud starts getting condensed and the matter around the core develops into small- rounded objects. These small- rounded objects by the process of cohesion develop into what is called planetesimals. Larger bodies start forming by collision, and gravitational attraction causes the material to stick together. Planetesimals are a large number of smaller bodies.

(iii) In the final stage, these large number of small planetesimals accrete to form a fewer large bodies in the form of planets.

## 4. EARTH'S ORBITAL PARAMETERS

**Standard orbital parameters**

Due to the shape of the described orbits, all the parameters are related to the ellipse.

Exist several parameters that let to describe an orbit that obeys Kepler's laws. While there are various ways to choose the parameters, the standard set follows:

The ones which describe the shape of the orbit:

(i) semi-major axis (a)

(ii) eccentricity (e)

The ones which describe the orientation of the orbit:

(i) inclination (i)

(ii) longitude of ascending node ($\Omega$)

(iii) argument of the perigee ($\omega$)

**The Ellipse**

A simple way to illustrate the ellipse is to picture a piece of string with each end fastened to fixed points called focus points or foci. The string length is arbitrarily set to 2a. The length of string remains constant at 2a, but the distance ($S_1$ and $S_2$) from the pencil to each focus will change at each point. The foci are located at F and F'.

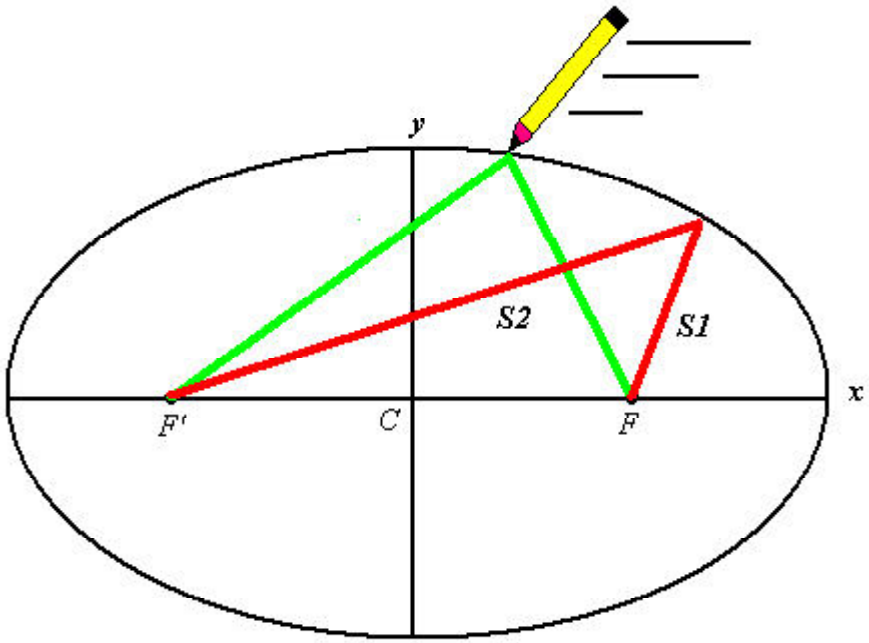



**Figure.A : Concept of Ellipse**

With this, the principal characteristic of the ellipse is that: if P is any point of the ellipse, PF + PF ' = 2a .

The ellipse's formula in Cartesian coordinates is (centred in one focus):

$$\frac{(x-c)^2}{a^2}+\frac{y^2}{b^2}=1$$

**Dimension Characteristics :**

(1) Longitude of major axis A'A = 2a

(2) Longitude of minor axis B'B = 2b

(3) Distance between the centre C and the foci (F or F') is

$$c = \sqrt{a^2 - b^2}$$

(4) Distance between the foci 2ae.

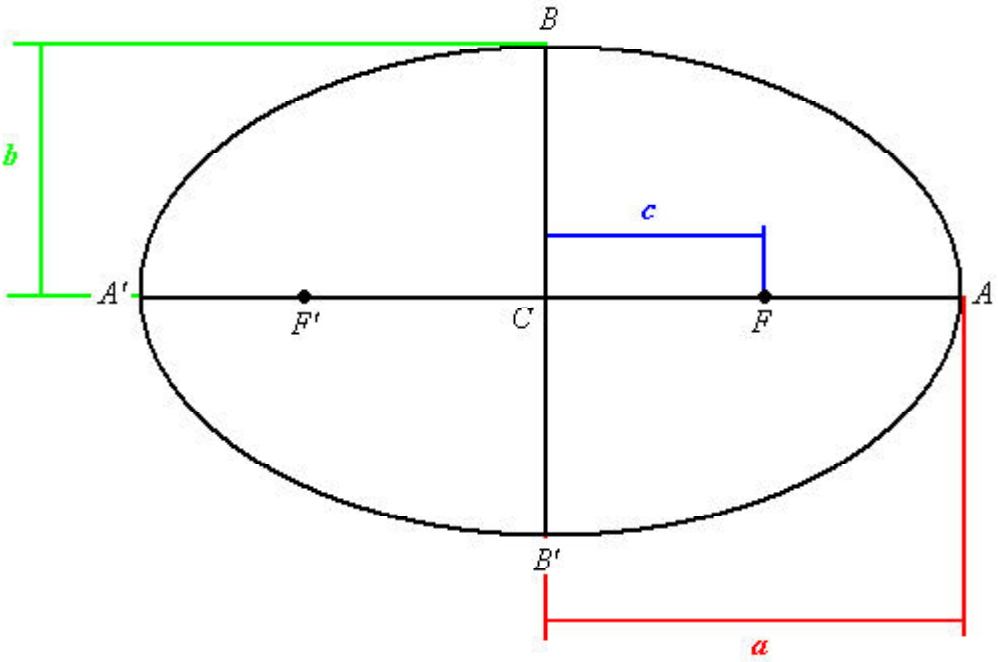



**Figure.B : Concept of Ellipse**

The radius (position vector magnitude) can be expressed as (ellipse centred in one focus):

$r = a\ (1 - e \cos E)$

or, in polar coordinates (ellipse centred in one focus):

$$r = \frac{a\left(1-e^2\right)}{1+e\cos\upsilon}$$

the conversion from polar to Cartesian (ellipse centred in one focus):

$$\boxed{\begin{aligned} x &= r\cos\upsilon = a\cos E - c \\ y &= r\sin\upsilon = b\sin E \end{aligned}}$$

where:

- $\upsilon$ is the true anomaly.
- E is the eccentric anomaly.
- a is the semi-major axis of the ellipse.
- b is the semi-minor axis of the ellipse.
- c is the center-focus distance of the ellipse.
- e is the eccentricity of the ellipse.

**Apoapsis, periapsis and line of apsides**

In astronomy, an apsis is the point of greatest or least distance of the elliptical orbit of a celestial body from its centre of attraction (the centre of mass of the system).

The point of closest approach is called the periapsis or pericentre and the point of farthest excursion is the apoapsis, apocentre or apapsis.

A straight line drawn through the periapsis and apoapsis is the line of apsides. This is the major axis of the ellipse, the line through the longest part of the ellipse.

Apsis is a general term. It is substituted to identify the body being orbited. In the following table some examples are specified.

| Body | Closest approach | Farthest approach |
|---|---|---|
| Galaxy | Perigalacticon | Apogalacticon |
| Star | Periastron | Apastron |
| Sun | Perihelion | Aphelion |
| Earth | Perigee | Apogee |
| Jupiter | Perijove | Apojove |

**Table: Examples of the apsis nomenclature**

**Semi-major and semi-minor axis**

The semi-major axis, a, is an orbital element that determines the shape of the orbit. It can be derived from the Mean Motion and the Eccentricity. If the orbit is a circle, the semi-major axis is the radius of the circle. If it is an ellipse, the major axis is the longest diameter, while the minor axis is the shortest. The semi-major axis is half the major axis; the semi-minor axis, b, is half the minor axis.

Note that for elliptical orbits, the Earth is at one **focus.** These points (the foci) are not centered in the ellipse, so the semi-major axis does not directly describe the altitude at perigee.

$$a = \sqrt[3]{\frac{\mu}{n^2}} = \frac{c}{e}$$

where:

- $\mu$ is the standard gravitational parameter
- n is the mean motion
- c is the center-focus distance of the ellipse
- e is the eccentricity of the ellipse

**Eccentricity**

The eccentricity, e, is an element that determines the shape of the orbit. It gives the information of how much the ellipse deviates from a circle. It can adopt several values, from 0 to $\infty$ :

e = 0 circle

e < 1 ellipse

e = 1 parabola

e > 1 hyperbola

$$e = \frac{c}{a} = \frac{\sqrt{a^2 - b^2}}{a}$$

where:

- a is the semi-major axis of the ellipse.
- b is the semi-minor axis of the ellipse.
- c is the center-focus distance of the ellipse.

**Inclination**

The inclination, i, is the angular distance of the orbital plane (in fact, the normal of the orbital plane) w.r.t a reference plane (for example, if the orbit is around the Earth, the reference plane is the equatorial or ecliptic plane).

Normally stated in degrees. 0° < i < 180°.

| | |
|---|---|
| i = 0° or 180° | equatorial orbit |
| i = 90° | polar orbit |
| 0° < i < 90° | direct orbit (or prograde) |
| 90° < i <180° | retrograde orbit |

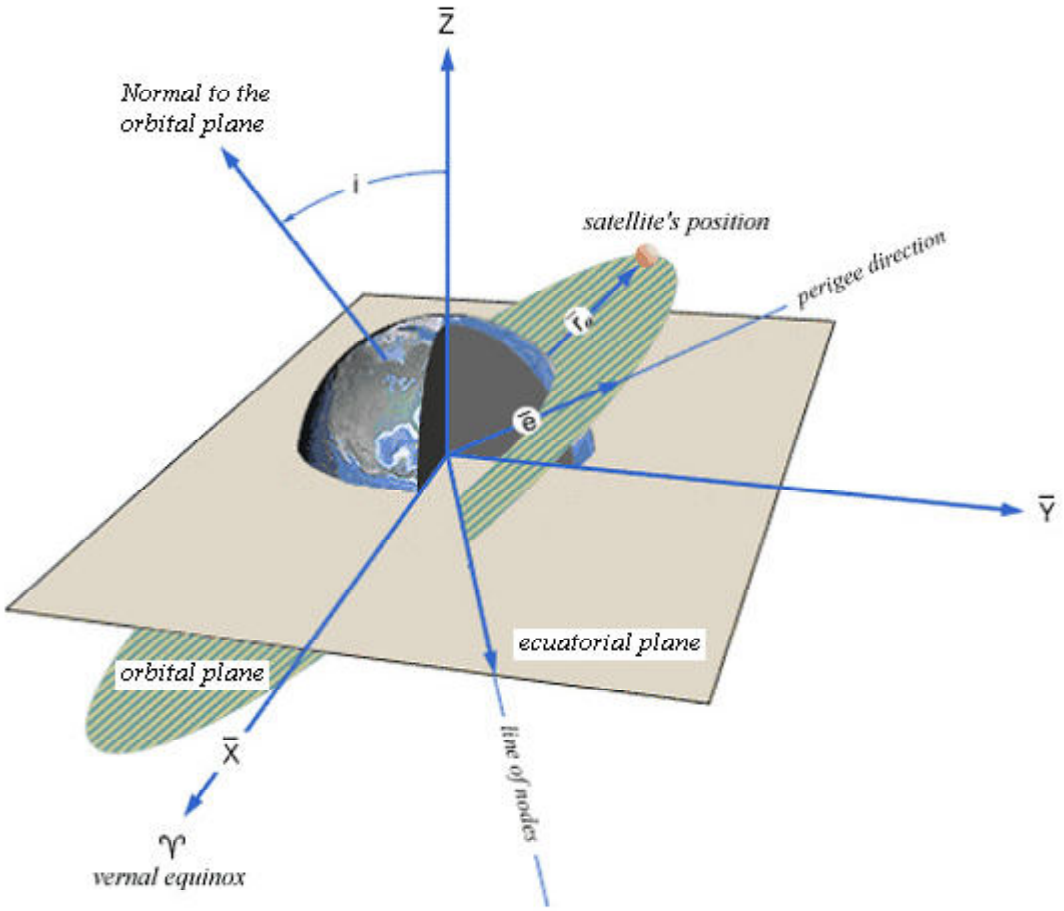



**Figure: Inclination**

**Longitude of the ascending node**

The nodes of an orbit are the points where it crosses a reference plane. The ascending node is the point at which the northbound (ascending) satellite crosses the equator (for the Earth's case), passing from the southern hemisphere to the northern hemisphere. The longitude of the ascending node, Ω, is the angle measured from the principal direction (longitude origin) to the ascending node in the counter clockwise direction. For a Sun-orbiting body, it is the angle formed at the Sun from the First Point of Aries (Vernal equinox) to the body's ascending node, measured in the reference plane (the ecliptic). 0° < Ω < 360°. It determines the orientation of the orbit.

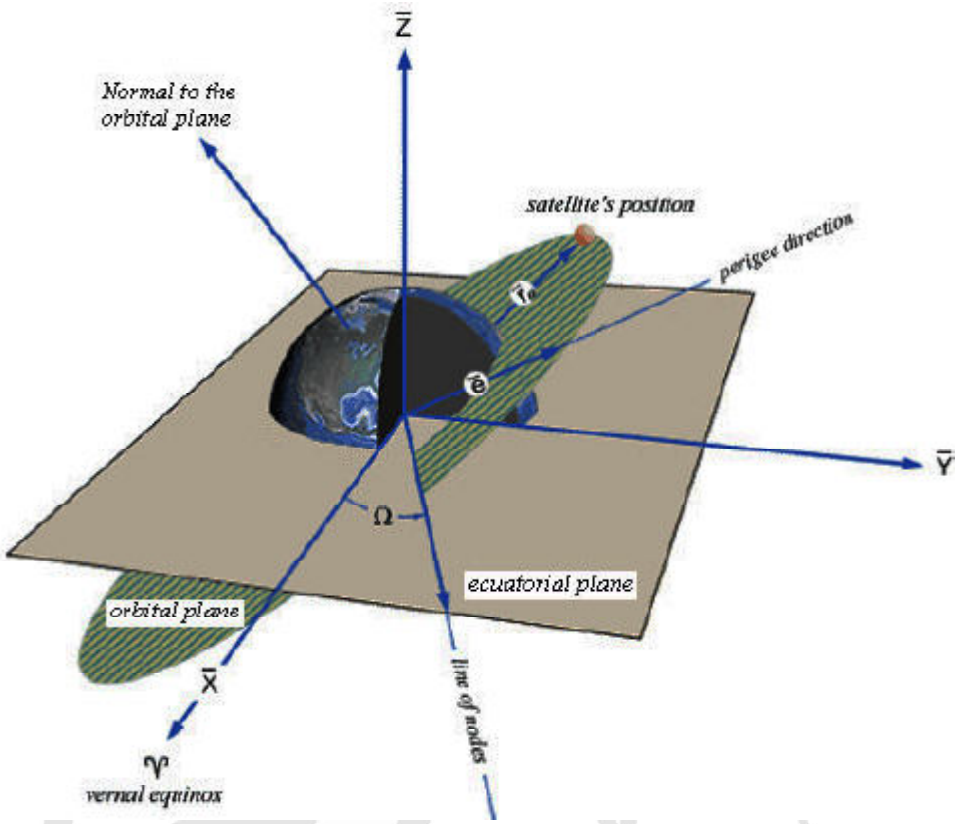



**Figure: Longitude of ascending node**

**Argument of perigee :**

The argument of perigee, ω, is the angle measured from the ascending node (or line of nodes) to the perigee in the counter clockwise sense. 0° < ω < 360° . It determines the orientation of the orbit inside its plane.

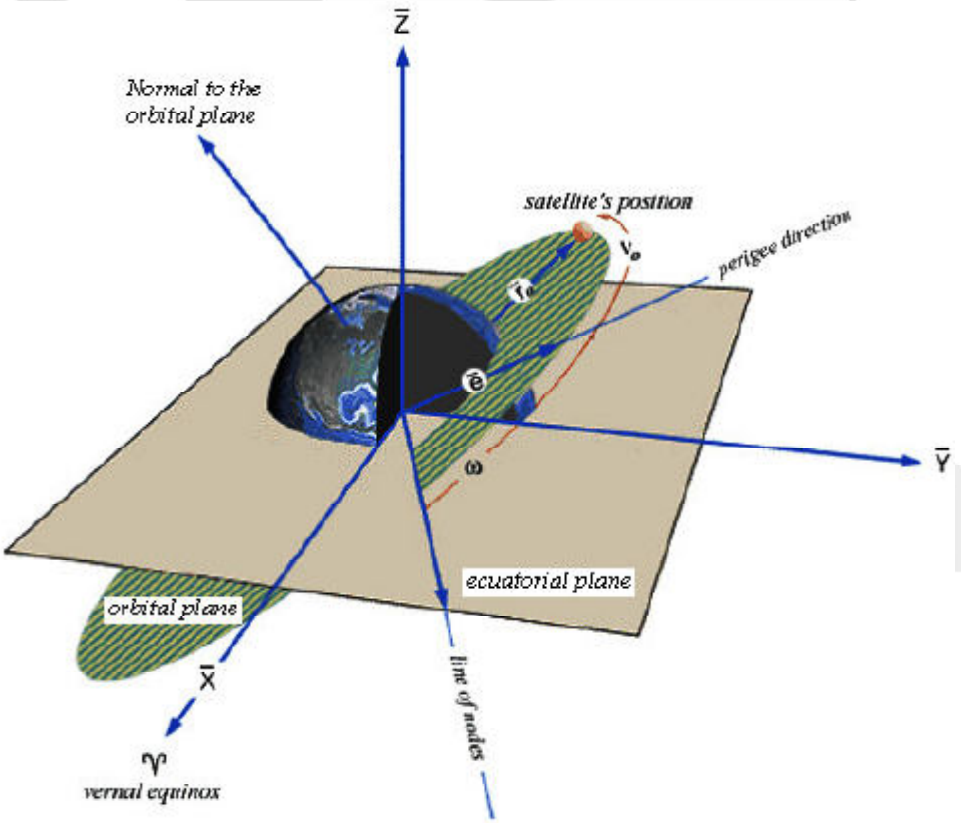



**Figure: Argument of Perigee**

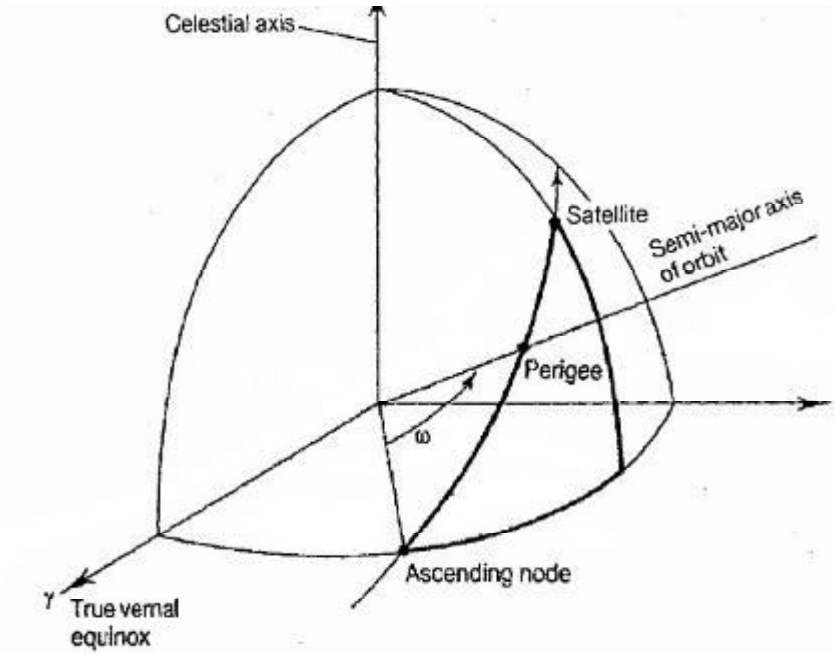



**Figure : Argument of perigee**

**True anomaly**

The true anomaly, $\upsilon$, is the angular distance, measured in the orbital plane, from the occupied focus (i.e. Earth's center) from the perigee to the current location of the satellite (orbital body). Countered in the direction of movement of the satellite. In degrees. $0° < \upsilon < 360°$.

$$\sin\upsilon = \frac{\sqrt{1-e^2}\sin E}{1-e\cos E}$$

$$\cos\upsilon = \frac{\cos E - e}{1-e\cos E}$$

$$\tan\frac{\upsilon}{2} = \sqrt{\frac{1+e}{1-e}}\tan\frac{E}{2}$$

where

- E is the eccentric anomaly.
- e is the eccentricity of the ellipse.

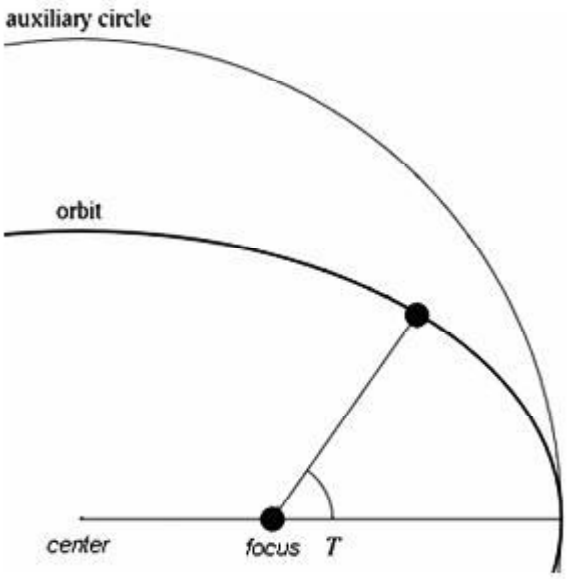



**Figure : True anomaly**

**Other parameters**

**Mean anomaly**

The mean anomaly, M, is the angle which describes the position of a satellite in its orbit, relative to perigee. At perigee, the Mean Anomaly is zero, it increases to 180 degrees at apogee, then back to perigee at 360 degrees. Since the orbit is often not a circle, the measurement of the angle is difficult, so the angle is expressed in terms of a fractional orbit (one orbit = 360 degrees).

This is the reason for the mean adjective. Anomaly is a term for an angle. For circular orbits, the mean anomaly is just the angle between perigee and the current satellite position.

$M = M_0 + n(t - t_0) = E - e \sin E$

The relation between M and E is the Kepler equation, where:

- $M_0$ is the mean anomaly at time $t_o$.
- $t_0$ is the start time
- t is the time of interest
- n is the mean motion
- E is the eccentric anomaly
- e is the eccentricity of the ellipse

**Eccentric anomaly**

The eccentric anomaly, E, is the angle between the direction of periapsis and the current position of an object on its orbit, projected onto the ellipse's circumscribing circle perpendicularly to the major axis, measured at the centre of the ellipse.

$$M = E - e\sin E$$

$$\sin\upsilon = \frac{\sqrt{1-e^2}\sin E}{1-e\cos E}$$

$$\cos\upsilon = \frac{\cos E - e}{1-e\cos E}$$

$$E = 2\arctan\sqrt{\frac{1-e}{1+e}}\tan\upsilon$$

where:

- M is the mean anomaly.
- $\upsilon$ is the true anomaly.
- e is the eccentricity of the ellipse.

Usually the used relation is the first one, solved iteratively (i.e. with the Newton-Raphson numerical method).

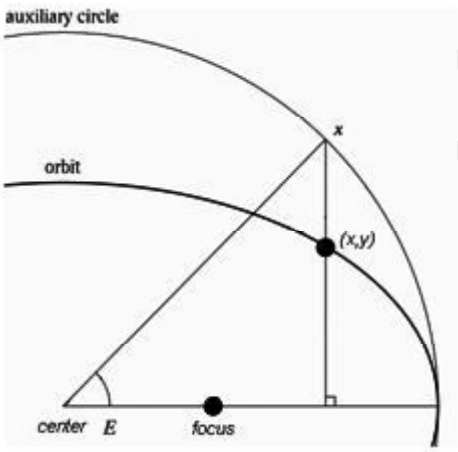



**Figure: Eccentric anomaly**

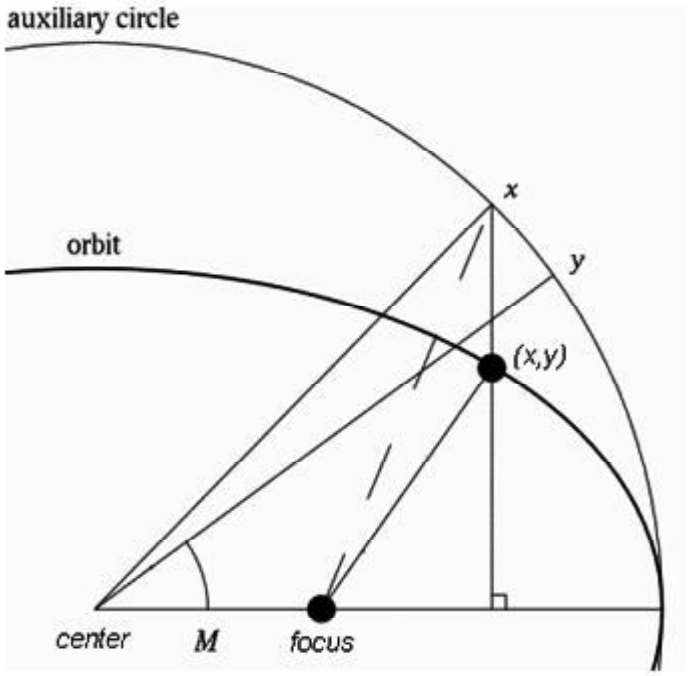



**Figure: Mean anomaly**

**Mean motion**

The mean motion, n, is a element (a number) that indicates the complete number of orbits a satellite makes in one day.

$$n = \frac{dM}{dt} = \sqrt{\frac{\mu}{a^3}}$$

where:

- M is the mean anomaly.
- t is the time.
- $\mu$ is the standard gravitational parameter.
- a is the semi-major axis of the ellipse.

**Period of orbit**

The period of orbit, P, is time it takes a satellite to complete one revolution (orbit).

$$P = \frac{2\pi}{n}$$

where, n is the mean motion.

**Standard gravitational parameter**

In astrodynamics, the standard gravitational parameter $\mu$, of a celestial body is the product of the gravitational constant G and its mass M. The units of the standard gravitational parameter are $km^3s^{-2}$

$$\mu = GM$$

**Table : Standard gravitational parameters of the Solar System**

| Body | $\mu\left(km^3s^{-2}\right)$ |
|---|---|
| Sun | 132,712,440,018 |
| Mercury | 22,032 |
| Venus | 324,859 |
| Earth | 398,600 |
| Mars | 42,828 |
| Jupiter | 126,686,534 |
| Saturn | 37,931,187 |
| Uranus | 5,793,947 |
| Neptune | 6,836,529 |
| Pluto | 1,001 |

**Time of Perigee Passage**

The time of perigee passage is the instant time when the satellite crosses its perigee.

**Semilatus Rectum**

The semilatus rectum, p, is the line parallel to the minor axis measured from the focus to the ellipse when the true anomaly, $\upsilon$, is 90°. Semilatus rectum is a compound of the Latin semi-meaning half, latus, meaning side and rectum, meaning straight,

$$p = a\left(1 - e^2\right) = \frac{b^2}{a}$$

where:

- a is the semi-major axis of the ellipse.
- b is the semi-minor axis of the ellipse.
- e is the eccentricity of the ellipse.

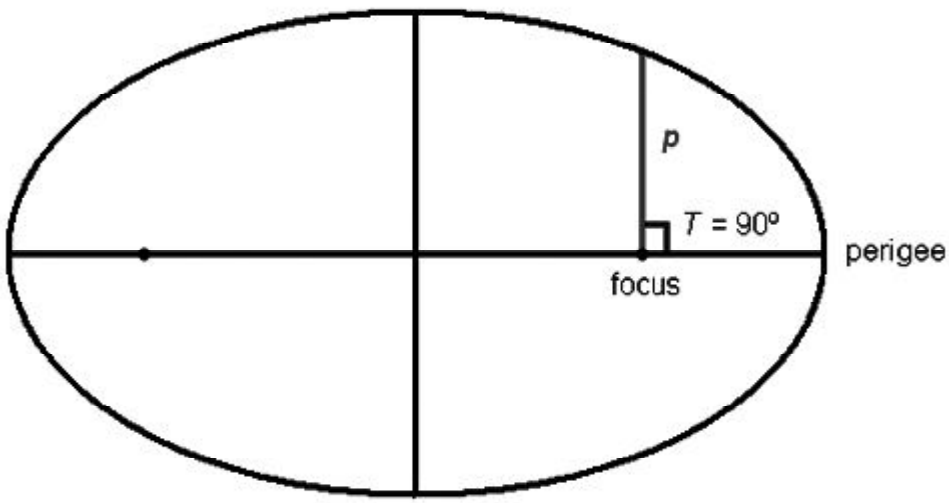



**Figure: Semilatus rectum**

## 5. KEPLER'S LAW OF PLANETARY MOTION

In astronomy, Kepler's laws given an approximate description of the motion of planets around the sun.

**Kepler's laws are:**

1. The orbit of every planet is an ellipse with the Sun at a focus.
2. A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

Kepler's laws were discovered empirically, around 1605, by Johannes Kepler who found them by analyzing the astronomical observations of Tycho Brahe. Almost a century later, lsaac Newton proved that relationships like Kepler's would apply exactly under certain ideal conditions approximately fulfilled in the solar system, as consequences of Newton's own laws of motion and law of universal gravitation, using classical Euclidean geometry.

Because of the non-zero planetary masses and resulting perturbations, Kepler's laws apply only approximately and not exactly to the motions in the solar system.

Kepler's laws and his analysis of the observations on which they were based, the assertion that the Earth orbited the sun, proof that the planets speeds varied, and use of elliptical orbits rather than circular orbits with epicycles - challenged the long- accepted geocentric models of Aristotle and Ptolemy, and generally supported the heliocentric theory of Nicolaus copernicus (although Kepler's ellipses likewise did away with Copernicus's circular orbits and epicycles). Together with Newton's mathematical theories they are part of the foundation of modern astronomy and physics after lsaac Newton showed that relationships of similar form would apply exactly as consequences of the laws of motion and gravitation under certain ideal conditions (not exactly fulfilled in the solar system).

Kepler's law are concerned with the motion of the planets around the sun. Newton's laws of motion in general are concerned with the motion of objects subject to impressed forces. Newton's law of universal gravitation describes how masses attract each other through the force of gravity. Using the law of gravitation to determine the impressed forces in Newton's laws of motion enables the calculation of planetary orbits, as discussed below.

While Kepler's laws are expressed either in geometrical language or as equations connecting the coordinates of the planet and the time variable with the orbital elements, Newton's second law is a differential equation. So the derivations below involve the art of solving differential equations. Kepler's second law is derived first, as the derivation of the first law depends on the derivation of the second law. The derivations that follow use heliocentric polar coordinates, that is polar coordinates with the Sun as the origin.

**Equations of Motion**

Assume that the planet is so much lighter than the sun that the acceleration of the sun can be neglected. In other words, the barycenter is approximated as the center of the sun. Introduce the polar coordinate system in the plane of the orbit, with radial coordinate from the sun's center r and angle from some arbitrary starting direction e.

Newton's law of gravitation says that "every object in the universe attracts every other object along a line of the centers of the objects, proportional to each object's mass and inversely proportional to the square of the distance between teh objects." and his second law of motion says that "the mass times the acceleration is equal to the force". So the mass of the planet times the acceleration vector of the planet equals the mass of the sun times the mass of the planet divided by the square of the distance, times minus the radial unit vector $\hat{r}$ times a constant of proportionality. This is written:

$$m\ddot{r} = -\frac{GMm}{r^2}\hat{r}$$

where a dot on top of the variable signifies differentiation with respect to time, the second dot indicates the second derivative, and the position vector $\mathbf{r} = r\,\hat{r}$

In polar coordinates, as discussed in vector calculus and polar coordinates in an inertial frame of reference.

$$\dot{\hat{r}} = \dot{\theta}\hat{\theta}$$

where $\hat{\theta}$ is the tangential (azimuthal) unit vector orthogonal to $\hat{r}$ pointing in the direction of rotation, and $\theta$ is the polar angle.

So differentiating the position vector $r = r\,\hat{r}$ twice to obtain the velocity and the acceleration vector:

$$\dot{r} = \dot{r}\,\hat{r} + \dot{r}\,\dot{\hat{r}} = \dot{r}\,\hat{r} + r\dot{\theta}\hat{\theta}$$

$$\ddot{r} = \left(\dot{r}\,\hat{r} + r\,\dot{\hat{r}}\right) + \left(r\dot{\theta}\hat{\theta} + r\ddot{\theta}\hat{\theta} + r\dot{\theta}\,\dot{\hat{\theta}}\right) = \left(\ddot{r} - r\dot{\theta}^2\right)\hat{r} + \left(r\ddot{\theta} + 2r\dot{\theta}\right)\hat{\theta}$$

Note that for constant distance r, the planet is subject to the centripetal acceleration, $r\dot{\theta}^2$, and for constant angular speed, $\theta$, the planet is subject to the coriolis acceleration, $2r\dot{\theta}$.

Inserting the acceleration vector into Newton's laws, and dividing by m, gives the vector equation of motion

$$\left(\ddot{r} - r\dot{\theta}^2\right)\hat{r} + \left(r\ddot{\theta} + 2\dot{r}\dot{\theta}\right)\hat{\theta} = -GMr^{-2}\,\hat{r}$$

Equation components we get the two ordinary differential equations of motion, one for the acceleration in the $\hat{r}$ direction, the radial acceleration

$$\ddot{r} - r\dot{\theta}^2 = -GMr^{-2},$$

and one for the acceleration in the $\hat{\theta}$ direction, the tangential or azimuthal acceleration:

$$r\ddot{\theta} + 2r\dot{\theta} = 0$$

**Deriving Kepler's first law**

To derive Kepler's first law, define :

$$u = pr^{-1}$$

where the constant

$$p = \ell^2\, G^{-1}\, M^{-1}$$

has the dimension of length. Then

$$GMr^{-2} = \ell^3\, p^{-3}u^2 \text{ and } \dot{\theta} = \ell r^{-2} = \ell p^{-2}u^2.$$

Differentiation with respect to time is transformed into differentiation with respect to angle:

$$\dot{X} = \frac{dX}{dt} = \frac{dX}{d\theta}.\frac{d\theta}{dt} = \frac{dX}{d\theta}.\dot{\theta} = \frac{dX}{d\theta}.\ell p^{-2}u^2$$

Differentiate

$$r = pu^{-1}$$

Twice

$$\dot{r} = \frac{d\left(pu^{-1}\right)}{d\theta}.\ell p^{-2}u^2 = -pu^{-2}\frac{du}{d\theta}.\ell p^{-2}u^2 = -\ell p^{-1}\frac{du}{d\theta}$$

$$\ddot{r} = \frac{d\dot{r}}{d\theta}.\ell p^{-2}u^2 = \frac{d}{d\theta}\left(-\ell p^{-1}\frac{du}{d\theta}\right).\ell p^{-2}u^2 = -\ell^2 p^{-3}u^2\frac{d^2u}{d\theta^2}$$

Substitute into the radial equation of motion

$$\ddot{r} = r\dot{\theta}^2 = -GMr^{-2}$$

and get

$$\left(-\ell^2 p^{-3}u^2\frac{d^2u}{d\theta^2}\right) - \left(pu^{-1}\right)\left(\ell p^{-2}u^2\right)^2 = \ell^2 p^{-3}u^2$$

Divide by $-\ell^2 p^{-3}u^2$ to get a simple non- homogeneous linear differential equation for the orbit of the planet :

$$\frac{d^2u}{d\theta^2} + u = 1$$

An obvious solution to this equation is the circular orbit u = 1.

Other solutions are obtained by adding solutions to the homogeneous linear differential equation with constant coefficients.

$$\frac{d^2u}{d\theta^2} + u = 0$$

These solution are = $u = \varepsilon.\cos\left(\theta - \theta_0\right)$

where $\varepsilon$ and $\theta_0$ are arbitrary constants of integration.

So the result is $u = 1 + \varepsilon.\cos(\theta - \theta_0)$

Choosing the axis of the coordinate system such that $\theta = 0$, and inserting $u = pr^{-1}$, gives :

$$pr^{-1} = 1 + \varepsilon.\cos\theta$$

If $|\varepsilon| < 1$, this is Kepler's first law.

**Deriving Kepler's Second Law :**

Only the tangential acceleration equation is needed to derive Kepler's second law.

The magnitude of the specific angular momentum $\ell = r^2\dot{\theta}$ is a constant of motion, even if both the distance r, and the angular speed $\dot{\theta}$, and the tangential velocity $r\dot{\theta}$, vary because

$$\frac{d\ell}{dt} = \frac{d\left(r^2\dot{\theta}\right)}{dt} = r^2\ddot{\theta} + 2r\dot{r}\dot{\theta} = r\left(r\ddot{\theta} + 2\dot{r}\dot{\theta}\right) = 0$$

Where the expression in the last parentheses vanishes due to the tangential acceleration equation.

The area swept out from time $t_1$ to $t_2$.

$$\int_{t_2}^{t_1}\frac{1}{2}.\text{base}.d(\text{height}) = \int_{t_2}^{t_1}\frac{1}{2}.r.r\dot{\theta}dt = \frac{1}{2}.\ell.\left(t_2 - t_1\right)$$

Depends only on the duration $t_2 - t_1$. This is Kepler's second law.

**Deriving Kepler's third law**

In the special case of circular orbits, which are ellipse with zero eccentricity, the relation between the radius a of the orbit and its period P can be derived relatively easily. The centripetal force of circular motion is proportional to $a/P^2$, and it is provided by the gravitational force, which is proportional to $1/a^2$. Hence

$$P^2 \propto a^3$$

which is Kepler's third law for the special case.

In the general case of elliptical orbits, the derivation is more complicated.

The area of the planetary orbit ellipse is

$$A = \pi ab = \pi a\left(a\sqrt{1-\varepsilon^2}\right) = \pi a^2\sqrt{1-\varepsilon^2}$$

The area speed of the radius vector sweeping the orbit area is

$$\dot{A} = \ell / 2$$

where

$$\ell^2 = pGM = a(1-\varepsilon^2)\ GM$$

The period of the orbit is

$$P = \frac{A}{\dot{A}} = \frac{\pi a^2\sqrt{1-\varepsilon^2}}{\ell/2} = 2\pi\frac{a^2\sqrt{1-\varepsilon^2}}{\ell}$$

Satisfying

$$\left(\frac{P}{2\pi}\right)^2 = \left(\frac{a^2\left(\sqrt{1-\varepsilon^2}\right)}{\ell}\right)^2$$

$$= \frac{a^4\left(1-\varepsilon^2\right)}{\ell^2} = \frac{a^4\left(1-\varepsilon^2\right)}{a\left(1-\varepsilon^2\right)GM} = \frac{a^3}{GM}$$

implying Kepler's third law

$$P^2 \propto a^3.$$

## 6. GEOLOGICAL TIME SCALE

The geologic time scale is a system of chronological measurement that relates stratigraphy to time, and is used by geologists, paleontologists, and other earth scientists to describe the timing and relationships between events that have occurred throughout Earth's history.

The table of geologic time spans presented here agrees with the dates and nomenclature set forth by the International commission on stratigraphy, and uses the standard color codes of the United States Geological Survey.

Evidence from radiometric dating indicates that the Earth is about 4.54 billion years old. The geology or deep time of Earth's past has been organized into various units according to events which took place in each period.

Different spans of time on the GTS are usually delimited by changes in the composition of strata which correspond to them, indicating major geological or paleontological events, such as mass extinctions.

For example, the boundary between the cretaceous period and the Paleogene period is defined by the Cretaceous - Paleogene extinction event, which marked the demise of the dinosaurs and many other groups of life.

Older time spans which predate the reliable fossil record (before the Proterozoic Eon) are defined by absolute age.

| Era | Period | Began (Million years ago) | Ended (Million years ago) | Major Events (million years ago) |
|---|---|---|---|---|
| Cenozoic | Quatemary | 1.6 | Present | Major Glaciers in North America and Europe (1.5) |
| | Tertiary | 65 | 1.6 | Rocky Mts (65) Individual Continents Take Shape |
| Mesozoic | Cretaceous | 146 | 65 | Dinosaurs Extract (65) Western Interior Seaway and Marine Reptiles (144-65) |
| | Jurassic | 208 | 146 | Pangaea (One land Mass) Begins to Break Up (200) |
| | Triassic | 245 | 20 | First Mammals and Dinosaurs |
| Paleozoic | Permian | 290 | 245 | Greatest Extinction on Earth (245) |
| | Pennsylvanian | 322 | 290 | First Reptiles |
| | Missiosippian | 362 | 322 | Coal- Forming forests |
| | Devonian | 408 | 362 | First Land Animals and First forests (408) |
| | Silurian | 439 | 408 | Life Invades Land |
| | Ordovician | 510 | 439 | First fish |
| | Cambrian | 545 | 510 | Great Diversity of Marine Invertebrates |
| Precambrian | Proterozoic | 2500 | 545 | Marine Fossil Invertebrates (600) |
| | Archean | 4600 | 2500 | Earliest Fossils Recorded (3,500) Earliest Rocks (4,000) |

**Age of the Earth**

- The age of the Earth is 4.54 $\pm$ 0.05 billion years (4.54 × 109 years $\pm$ 1%). This age is based on evidence from radiometric age dating of meteorite material and is consistent with the ages of the oldest - known terrestrial and lunar samples. Following the scientific revolution and the development of radiometric age dating, measurements of lead in uranium - rich minerals showed that some were in excess of a billion years old.
- The oldest such minerals analyzed to data - small crystals of zircon are at least 4.404 billion years old. Comparing the mass and luminosity of the sun to the magnitudes of other stars, it appears that the solar system cannot be much older than those rocks.
- Ca-Al- rich inclusions (inclusions rich in calcium and aluminium) - the oldest known solid constituents within meteorites that are formed within the solar system - are 4.567 billion years old, giving an age for the solar system and an upper limit for the age of Earth.
- It is hypothesized that the accretion of Earth began soon after the formation of the Ca-Al-rich inclusions and the meteorites. Because the exact accretion time of Earth is not yet known, and the predictions from different accretion models range from a few millions up to about 100 million years, the exact age of Earth is difficult to determine.
- It is also difficult to determine the exact age of the oldest rocks on Earth, exposed at the surface, as they are aggregates of minerals of possibly different ages.
- On the basis of theory, it was estimated that about 26 million years must have elapsed in accumulating 2,60,000 ft of shale deposit in the Green river lake of Colorado. These deposits were thus calculated to be 26 million years old. Another theory suggested for determining the age of the earth, was on the principle of determining the amount of total salt that has got accumulated in the oceans, and the rate of accumulation of such salt.
- All these older methods have now been dismissed and have become obsolete, with the advent of the modern radioactivity method.

**Dating of Rulers**

- On our earth, certain radioactive elements, like Uranium, Thorium, Strontium, Potassium, etc. are there. The atom of these radioactive elements are unstable, and are actually in a process of constant and spontaneous disintegration. This disintegration continues at a definite rate, till all the unstable atoms are completely converted into stable forms, given rise to an end product. Uranium, for example, disintegrates at a very slow rate to ultimately form an end product called radioactive lead.
- The most important aspects of using this method, are the facts:
  - (i) Radioactive elements are found buried in various rocks, although not in every rock, and hence the radiometric dating is limited to only those rocks which contain radioactive minerals.
  - (ii) The rate of radioactive decay is absolutely constant, and is not affected by changes in heat, pressure or chemical conditions.
  - (iii) As the parent radioactive element disintegrates, new materials will be formed and these can clearly be recognized and measured. Hence by knowing the amount of disintegration product of a radioactive element, and dividing it by the rate of formation of that product, we can very easily calculate the time that has elapsed since the first occurrence of that radioactive element.
- The rate of decay of the radioactive elements is generally expressed in terms of their half life period. Half life of these elements may be defined as the time taken by half of the element sample to get decayed into its end product. This half life period of different radioactive substances vary considerably from a fraction of a second to billions of years.

But with the exception of carbon 14($C^{14}$), the radioactive materials used to data back the rocks, have very long half lives.

- One of the most widely used radiometric dating method utilizes Uranium 238 (U238), which disintegrates through a distinct series of 14 steps, resulting in the decay product of Lead 206 ($Pb^{206}$). The time it takes for half of the original amount of material to change into $Pb^{206}$ (i.e., the half life of U238) is a constant 4.49 billion years.
- This incredibly long life of $U^{238}$ renders it especially useful in dating excrement old rocks. In fact, it is the method (i.e. analyzing the presence of $U^{238}$ and its end product in a sample of rock) which has been used to data the oldest rocks yet discovered.
- These ancient intrusive igneous rocks are located in Canada and Africa, and have been assigned ages of about 3.6 billion (3600 Million) years, which gives us the idea about the age of the earth, which has been estimated to be of the order of 4.5 to 5 billion years.
- Other radioactive elements that can be used for radiometric dating include.

(a) Rubidium 87($Rb^{87}$) with half life of 47 billion years, and given end product of strontium 87 ($Sr^{87}$) ; and (b) Thorium 232($Th^{232}$) with half life of 13.9 billion years, and giving end product (i.e., daughter product) of lead 208 ($Pb^{208}$). Unfortunately, these radioactive elements are not much more abundant than Uranium and consequently are of limited use.

Another important radiometric dating method, which may be used for determining the age of comparatively newer formations, involves the use of Potassium 40 ($K^{40}$) that can be detected even in minute quantities. The fact that potassium is a common constituent of igneous rocks plus the fact that its half life period is 1.31 billion years, has made Potassium - Argon method a most widely employed radiometric dating technique now in use.

These radiometric dating techniques, though to be quiet reliable, suffers from certain drawback and limitations, as pointed out below :

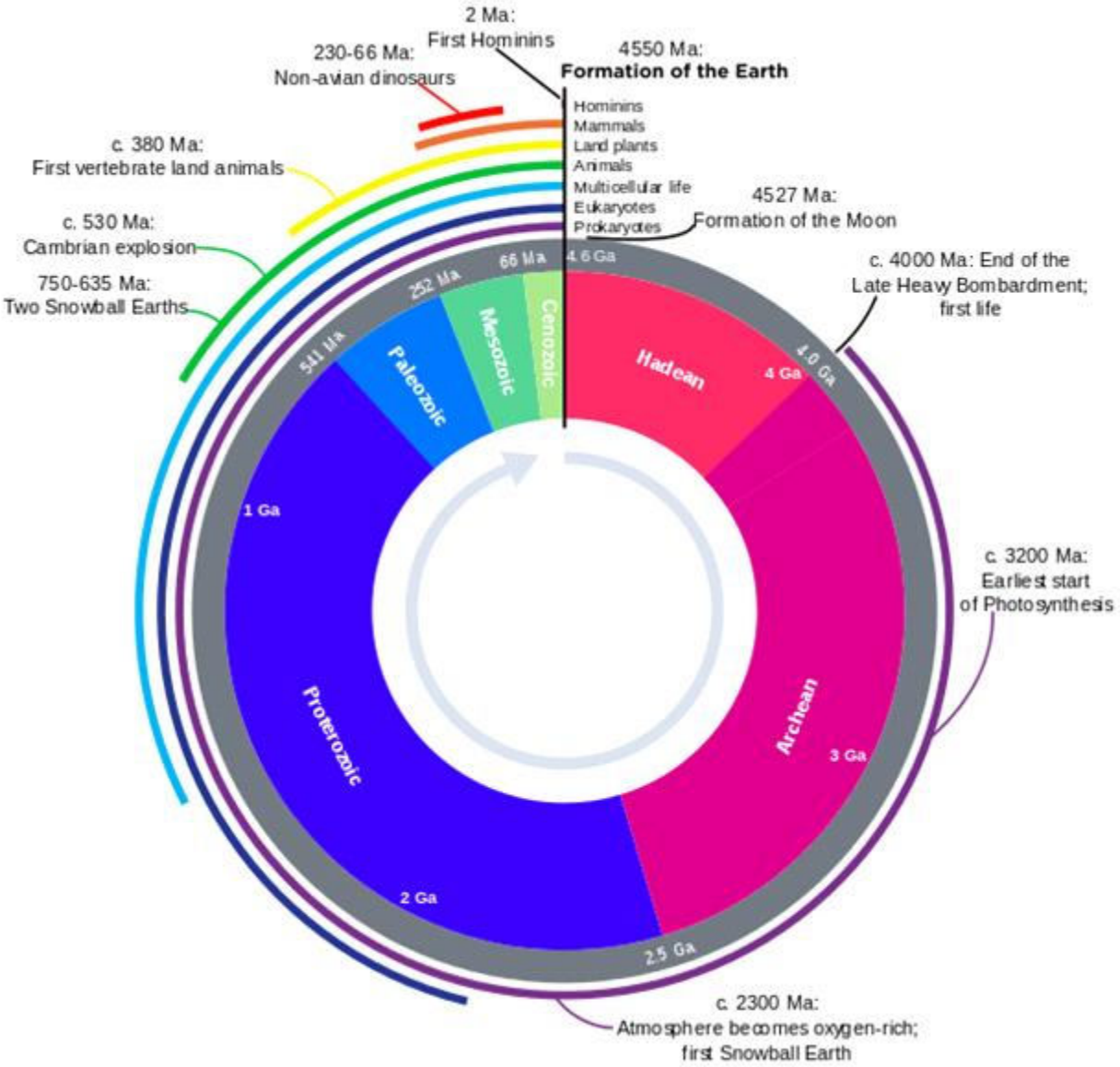
**(i)** **Sample Purity :** The mineral sample must be highly pure, from which neither the radioactive elements nor their disintegration products should have been lost even in the minutes quantities. For example, if a gas is formed as an intermediate product during the process of disintegration of the radioactive element, it must not get escaped as otherwise, the final end product would be less than what should have been its true value.

It is known that a gas Radon is formed as in intermediate product during the disintegration of $U^{238}$. Hence, if the environment of transformation is not fully captive some part of this gas may escape, resulting in lesser apparent quantities of ultimate product i.e., Lead. Similarly, none of the disintegration products should get added to the sample after its original formation.

**(ii)** **Experimental Accuracy :** Radiometric age determination techniques require a very accurate and precise analysis of determining the very minor quantities of radioactive elements and their end products and a host of their isotopes. Even a very small error may give highly erroneous results.

For example if the accurate amounts of Lead 206 and its isotope Lead 207 are not exactly determined in uranium sample, the calculated age may be millions of years away from the actual one

**Geologic Time :**




Geological time put in a diagram called a geological clock, showing the relative length of the eon of the Earth's history.

The geologic time scale encompasses the history of the Earth. It is bracketed at the old end by the dates of the earliest solar system material at 4.567 Ga, (giga annum : billion years ago) and the age of the Earth at 4.54 Ga at the beginning of the informally recognized Hadean eon. At the young end of the scale, it is bracketed by the present day in the Holocene epoch.

**Important Milestones**

- 4.567 Ga : Solar system formation
- 4.54 Ga : Accretion of Earth
- c.4 Ga : End of Late Heavy Bombardment, first life
- c. 3.5 Ga : Start of photosynthesis
- c. 2.3 Ga : Oxygenated atmosphere, first snowball Earth
- 730-635 Ma (mega annum : million years ago); two snowball Earths
- 542 $\pm$0.3 Ma : Cambrian explosion - vast multiplication of hard- bodied life ; first abundant fossils; start of the Paleozoic

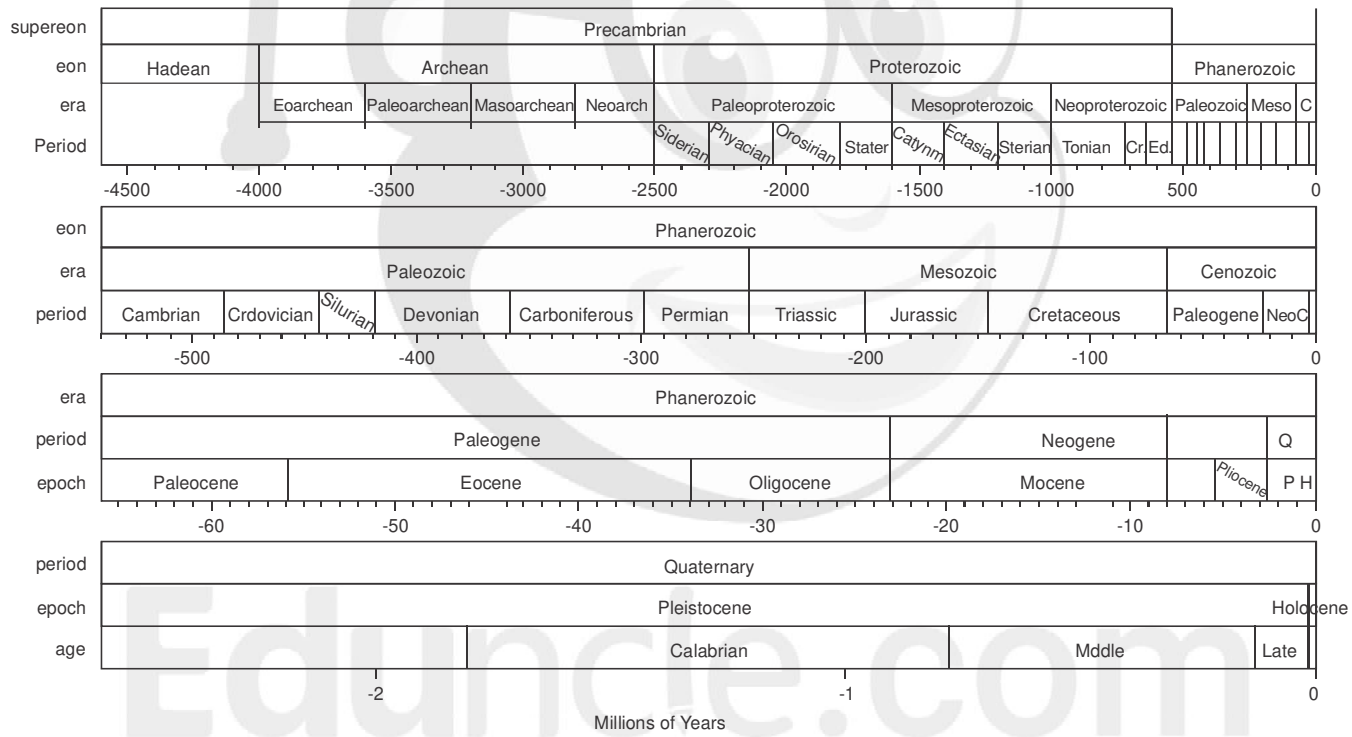
- c. 380 Ma : First vertebrate land animals
- 250 Ma : Permain - Triassic extinction - 90% of all land animals die. End of Paleozoic and beginning of Mesozoic
- 65 Ma : Cretaceous - Paleogene extinction - Dinosaurs die; end of Mesozoic and beginning of Cenozoic
- c. 7 Ma - Present : Hominins

  c. 7 Ma - First hominins appear
- 3.9 Ma : First Australopithecus, direct ancestor to modern Homo sapiens appear
- 200 Ka (Kiloannum : thousand years ago) : First modern Homo sapiens appear in East Africa

**Brief time Scale :**

The following four timelines show the geologic time scale. The first shows the entire time from the formation of the Earth to the present, but this compresses the most recent eon.

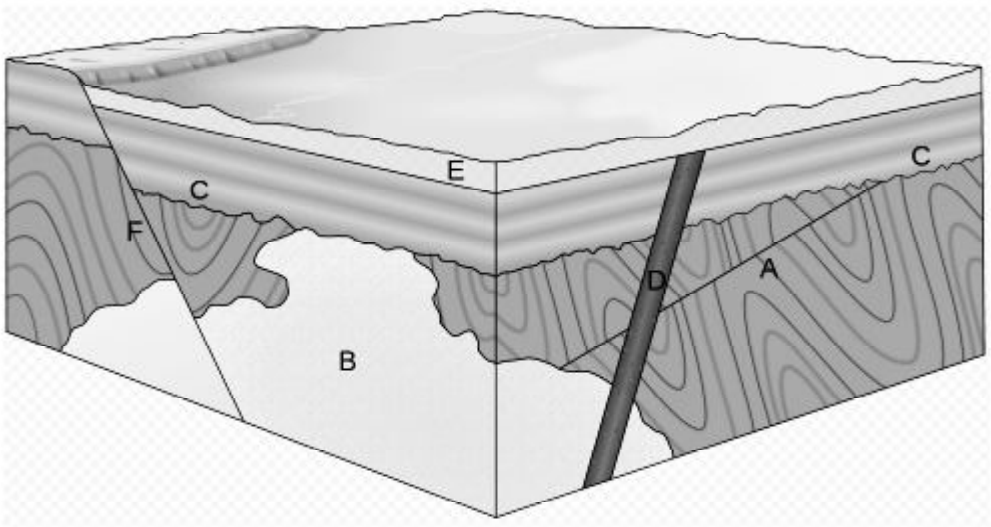
Therefore the second scale shows the most recent eon with an expanded scale. Finally, the second scale again compresses the most recent era, so the latest era is expanded in the third scale. Since the Quaternary is a very short period with short epochs, it is expanded in the fourth scale. The second, third, and fourth timelines are therefore each subsections of their preceding timeline as indicated by asterisks. The Holocene (the latest epoch) is too small to be shown clearly on the third timeline on the right, another reason for expanding the fourth scale. The Pleistocene (P) epoch, Q stands for the Quaternary period.




**Relative and absolute Dating :**

Geological events can be given a precise data at a point in time, or they can be related to other events that came before and after them. Geologists use a variety of methods to give both relative and absolute dates to geological events, then they use these dates to find the rates at which processes occur.

**Relative Dating:**




Cross- cutting relations can be used to determine the relative ages of rock strata and other geological structures. Explanations : A - folded rock strata cut by an thrust fault ; B - large intrusion (cutting through A); C - erosional angular unconformity (cutting off A & B) on which rock strata were deposited ; D - volcanic dyke (cutting through A, B & C); E- even younger rock strata (overlying C & D); F- normal fault (cutting through A, B, C & E).

Methods for relative dating were developed when geology first emerged as a formal science . Geologists still use the following principles today as a means to provide information about geologic history and the timing of geologic events.

The **principle of Uniformitarianism** states that the geologic processes observed in operation that modify the Earth's crust at present have worked in much the same way over geologic time. A fundamental principle of geology advanced by the 18th century Scottish physician and geologist James Hutton is that " the present is the key to the past". In Hutton's words. " the past history of our globe must be explained by what can be seen to be happening now."

**The principle of intrusive relationships** concerns crosscutting intrusions. In geology, when an igneous intrusion cuts across a formation of sedimentary rock, it can be determined that the igneous intrusion is younger than the sedimentary rock. There are a number of different types of intrusions, including stocks, laccoliths, sills and dikes.

**The principle of cross- cutting relationships** pertains to the formation of faults and the age of the sequences through which they cut. Faults are younger than the rocks they cut; accordingly, if a fault is found that penetrates some formations but not those on top of it, then the formations that were cut are older than the fault, and the ones that are not cut must be younger than the fault. Finding the key bed in these situations may help determine whether the fault is a normal fault or thrust fault.

**The principle of inclusions and components** states that, with sedimentary rocks, if inclusions (or clasts) are found in a formation, then the inclusions must be older than the formation that contains them. For example, in sedimentary rocks, it is common for gravel from an older formation to be ripped up and included in a newer layer. A similar situation with igneous rocks occurs when xenoliths are found. These foreign bodies are picked up as magma or lava flows, and are incorporated, later to cool in the matrix. As a result, xenoliths are older than the rock which contains them.

The Permian through Jurassic stratigraphy of the Colorado Plateau area of south - eastern Utah is a great example of both Original Horizontality and the law of Superposition. These strata make up much of the famous prominent rock formations in widely spaced protected areas such as capitol Reef National park and canyonlands National Park. From top to bottom: Rounded tan domes of the Navajo

Sandstone, layered red Kayenta formation, cliff- forming, vertically jointed, red wingate sandstone slope-forming, purplish chinle formation, layered lighter- red Moenkopi formation and white layered culter formation sandstone. Picture form glen canyon National Recreation Area, Utah.

The principle of original horizontality states that the deposition of sediments occurs as essentially horizontal beds. Observation of modern marine and non- marine sediments in a wide variety of environments supports this generalization (although cross- bedding is inclined, the overall orientation of cross- bedded units is horizontal).

The principle of superposition states that a sedimentary rock layer in a tectonically undisturbed sequence is younger than the one beneath it and older than the one above it. Logically a younger layer cannot slip beneath a layer previously deposited. This principle allows sedimentary layers to be viewed as a form of vertical time line, a partial or complete record of the time elapsed from deposition of the lowest layer to deposition of the highest bed.

The principle of faunal succession is based on the appearance of fossils in sedimentary rocks. As organisms exist at the same time period throughout the world, their presence or (sometimes) absence may be used to provide a relative age of the formations in which they are found. Based on principles laid out by Willian Smith almost a hundred years before the publication of Charles Darwin's theory of evolution, the principles of succession where developed in- dependently of evolutionary thought. The principle becomes quite complex, however, given the uncertainties of fossilization, the localization of fossil types due to lateral changes in habitat (facies change in sedimentary strata), and that not all fossils may be found globally at the same time.

**Absolute Dating**

Geologists can also give precise absolute dates to geologic events. These dates are useful on their own, and can also be used in conjunction with relative dating methods or to calibrate relative dating methods.

A large advance in geology in the advent of the 20th century was the ability to give precise absolute dates to geologic events through radioactive isotopes and other methods. The advent of radiometric dating changed the understanding of geologic time. Before, geologists could only use fossils to data sections of rock relative to one another. With isotopic dates, absolute dating became possible and these absolute dates could be applied fossil sequences in which there was datable material, converting the old relative ages into new absolute ages.

For many geologic applications, isotope ratios are measured in minerals that give the amount of time that has passed since a rock passed through its particular closure temperature, the point at which different radiometric isotopes stop diffusing into and out of the crystal lattice. These are used in geochronologic and thermochronologic studies. Common methods include uranium lead dating, potassium - argon dating and argon - argon dating, and uranium - thorium dating. These methods are used for a variety of applications. Dating of lavas and ash layers can help to date stratigraphy and calibrate relative dating techniques. These methods can also be used to determine ages of pluton emplacement. Thermochemical techniques can be used to determine temperature profiles within the crust, the uplift of mountain ranges, and uplift of mountain ranges, and pale. Fractionation of the lanthanide series elements is used to compute ages since rocks were removed from the mantle.

Other methods are used for more recent events. Optically stimulated luminescence and cosmogenic radionuclide dating are used to date surfaces and/or erosion rates. Dendrochronology can also be used for the dating of landscapes. Radiocarbon dating is used for young organic material.

# 7. ATMOSPHERE AND OCEANS

## THE ATMOSPHERE

- The outer gaseous part of the Earth starting from the surface and extending as far as 700 km and even beyond is termed as atmosphere. It makes only about one- millionth part of the total mass of the Earth.
- The gaseous envelope, like the other matter, is held around the planet due to gravitational pull of the body of the Earth. It is now fairly established that the atmosphere possesses a layered structure. Different layers of the atmosphere are distinguished on a number of basis: change in composition, change in temperature, degree of ionization and so on.
- Chemically speaking, the atmosphere is made up of a mechanical mixture of gases commonly called air that has a fairly uniform composition and homogeneous structures as follows:

**Table : Chemical Composition of Atmosphere (Dry Air).**

| Component | Volume Percentage |
|---|---|
| Nitrogen | 78.084 |
| Oxygen | 20.946 |
| Argon | 00.934 |
| Carbon dioxide | 00.033 |
| Others (Ne, He, Kr, Xe etc.) | 00.003 |

- The above composition of the atmosphere is almost uniform upto a height of 80 km from the surface. This atmospheric zone of uniform composition is some times referred as homosphere to differentiate it from the overlying part forms the heterosphere where the composition varies from place to place. Thermally speaking the atmosphere shows an interesting variation in temperature with increasing height from the surface.
- At some levels the temperature starts falling with increasing height whereas at other levels, it remains constant with increasing height and then at still other levels the temperature starts rising. Thus a zigzag curve is obtained for variation of temperature records in the atmosphere above the surface. (Figure.1)
- Based on thermal characters, the atmosphere is divided into following layers, troposphere, stratosphere, mesosphere and thermosphere (Figure.2) Following are the main characteristics of these atmospheric zones :

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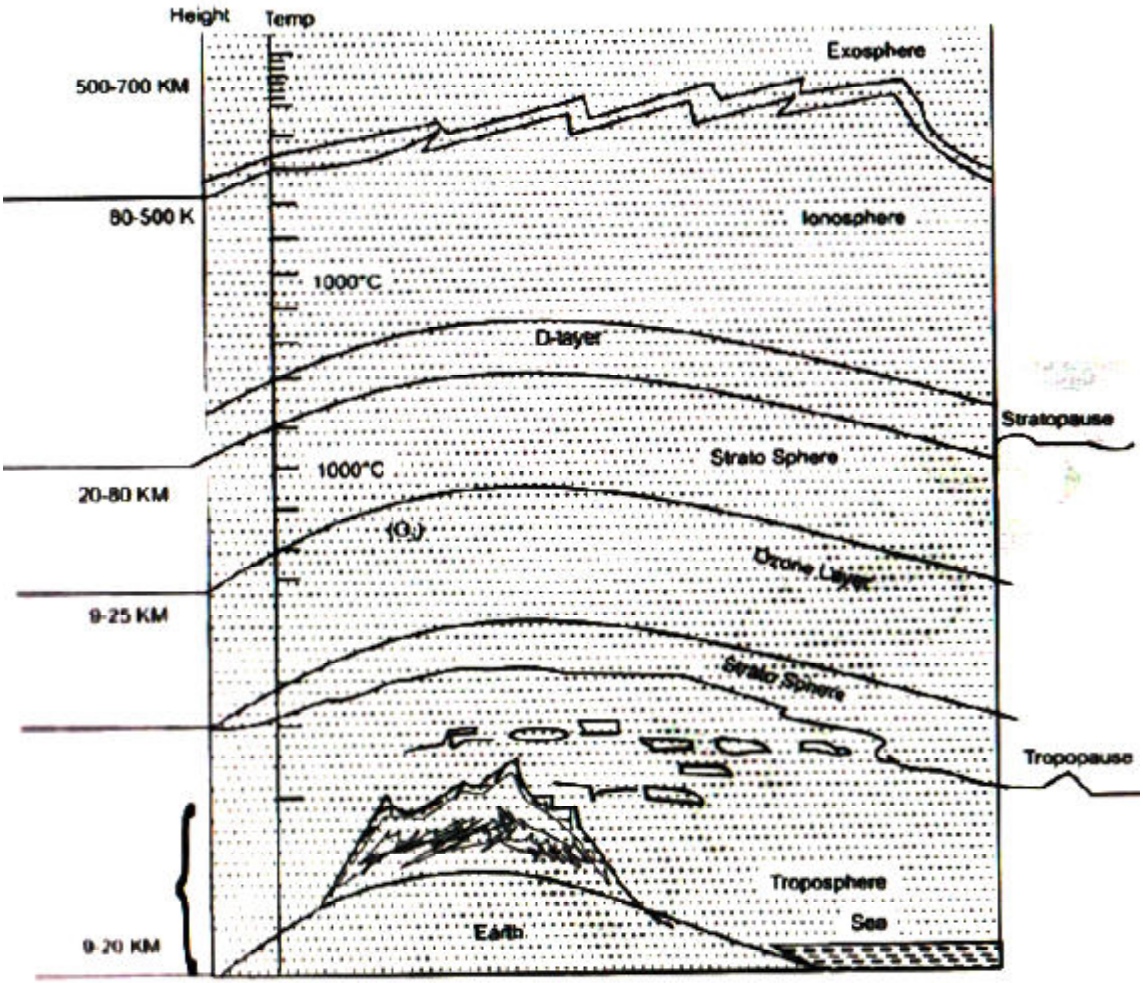
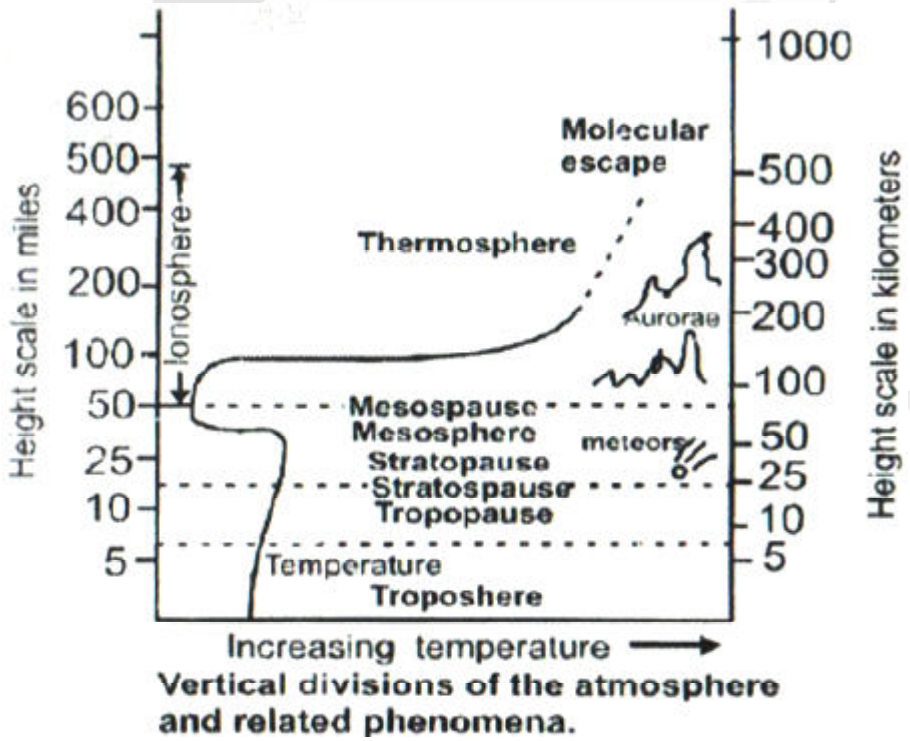



**Figure.1 : Structure of the Atmosphere**




**Vertical divisions of the atmosphere and related phenomena.**

**Figure.2**

## OCEANS

### Continents and Ocean Basins

- 29% of the Earth's surface is land and 71% of its surface is water.
- Ocean crust consists almost entirely of basalt (thinly covered by sediments).
- Compared to the continental crust (on average over a billion years old) the ocean crust is much younger (less than 200 million years old, on average less than 60 million years old).

### The Midoceanic Ridge

- A typical ocean basin is characterized by a central structure that divides the basin more or less in half (a midocean ridge).
- Midocean ridges consist of submarine hills that rise gradually to a rugged central zone (the highest point along the ridge; the axial rift).
- The midoceanic ridge and its principal branches can be traced through the ocean basins for a distance of over 60,000 km.

### The Ocean Basin Floor

- Abyssal plains on either side of midoceanic ridges are deep (average depth of 5000 m below sea level) plains coated with fine sediment.

### Oceanic Crust

- Oceanic crust, is mostly basalt, a fine- grained rock rich in minerals containing iron and magnesium.
- Oceanic lithosphere has a maximum thickness of about 100 km (62 mi) whereas continental lithosphere ranges in thickness from 100 to 150 km (62 to 93 mi).

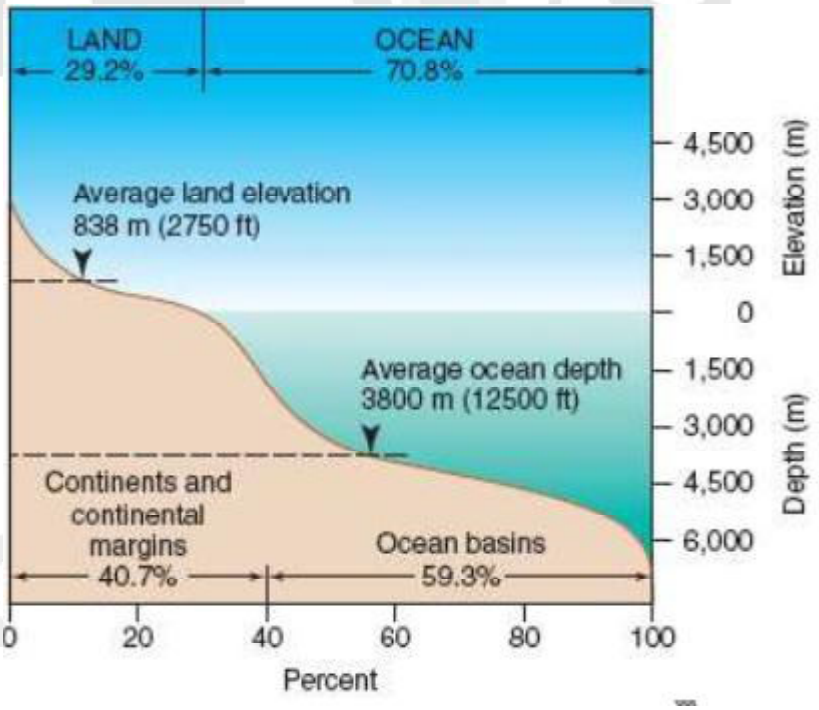



**Figure.3 Hypsographic curve of Earth's surface, showing the relative distribution of ocean and land.**

### Ocean Bottom Profile

- Ocean depth varies markedly from one place to another.
- Over large areas water depth is less than 200 m (650 ft) ; in other areas the water is as deep as 11,000 m (36,000 ft).

- Average ocean depth is about 3800 m (12,500 ft).
- The vertical cross- sectional profile of the ocean bottom, includes the continental margin and ocean basin.
- In places the ocean bottom is nearly flat and essentially featureless whereas in other places the ocean floor exhibits considerable topographic relief.
- Parts of the ocean bottom are volcanically active with lava interacting chemically with seawater.

**Ocean Basins**

- Ocean basins have a varied topography featuring deep trenches, sea mounts, and submarine mountain ranges.
- Much of the ocean bottom (about 42%) is comprised of plains and low hills, most rising no more than about 100 m (330 ft) above the plain.
- Blanketed with sediments that tend to smooth out any irregularities in the bedrock below, abyssal plains and abyssal hills are typical of ocean basin topography- apart from the 23% the ocean bottom that is covered by ridge systems.

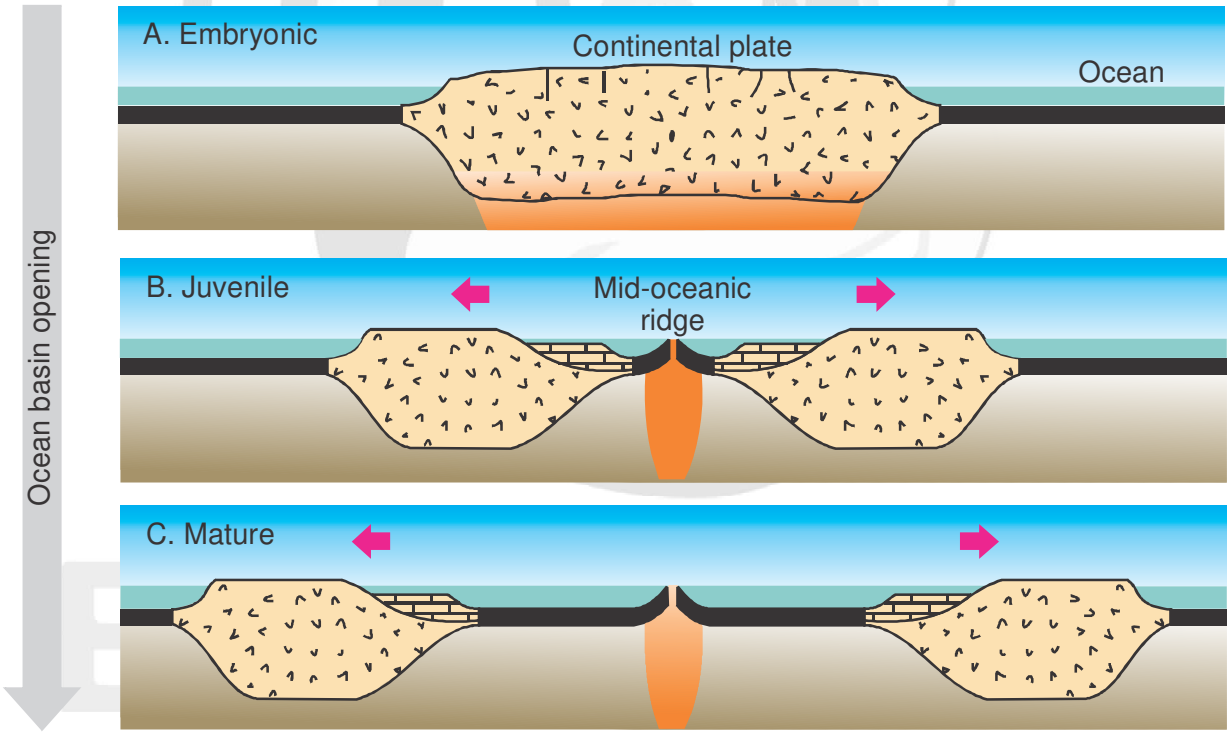
**Ocean Ridges**

- Ocean ridges are characterized by shallow earthquakes limited to axial rift zones.
- These earthquakes are generally small in magnitude, commonly occur in swarms and appear to be associated with intrusion and extrusion of basaltic magmas.
- The ocean basins have magnetic reversal natural.

**WILSON CYCLE**

- Cycles of ocean basin spreading and closing are called Wilson cycles after the Canadian geologist J. Tuzo Wilson (1908-1993) who first recognized and described the stages in the life span of an ocean basin.
- A Wilson cycle consists of six stages : embryonic, juvenile, mature, declining terminal and suturing.
- The cycle begins because thick continental crust does not conduct heat as readily as thinner oceanic crust.
- A supercontinent that remains in one location for hundreds of millions of years acts like a blanket, retarding heat flow from Earth's interior.
- This causes the mantle beneath the supercontinent to warm.
- As the underlying mantle warms, it expands, elevating the overlying continent and stretching the continental crust.
- Convection currents in the mantle also contribute to this stretching and eventually the crust fractures, forming a rift valley.
- With rifting of the continental crust, the broken sides rise about a kilometer enclosing a valley that often fills with fresh water.
- In East Africa, long, deep lakes now occupy narrow rift valleys.
- Rift valleys gradually widen and eventually connect to the ocean and the freshwater lakes become narrow saline gulfs.
- The divergent plate boundary widens and additional oceanic crust is generated signaling the mature stage of the wilson cycle.
- Today, the atlantic is a mature ocean with geologically passive margins.
- Subduction becomes more widespread around the border of the ocean basin during the declining stage of the Wilson cycle.

- In time, cooling and the loss of volatiles increase the density of oceanic plates.
- Under the influence of gravity, these plates slide down and away from the topographic high of the mid- oceanic ridge and sink into the as thenosphere at subduction zones.
- Following the declining stage of the Wilson cycle, the ocean basin closes through subduction as continents from opposite sides of the ocean basin bear down on one another and eventually collide.
- These events signal the final two stages of the Wilson cycle : the terminal and suturing stages.
- In the terminal stage, the continents are not yet touching but subduction of the intervening oceanic crust causes a narrowing of the sea separating the continents.
- Volcanic eruptions, earthquakes, uplift, and mountain building accompany subduction of the oceanic crust.
- During the suturing stage, collision of the continents is complete and the intervening sea is gone.
- The two colliding continental crusts, being less dense than the oceanic crust, do not subduct but rather override one another causing uplift and mountain building.
- Collision of the continents squeezes out the intervening ocean and causes subduction of oceanic crust.



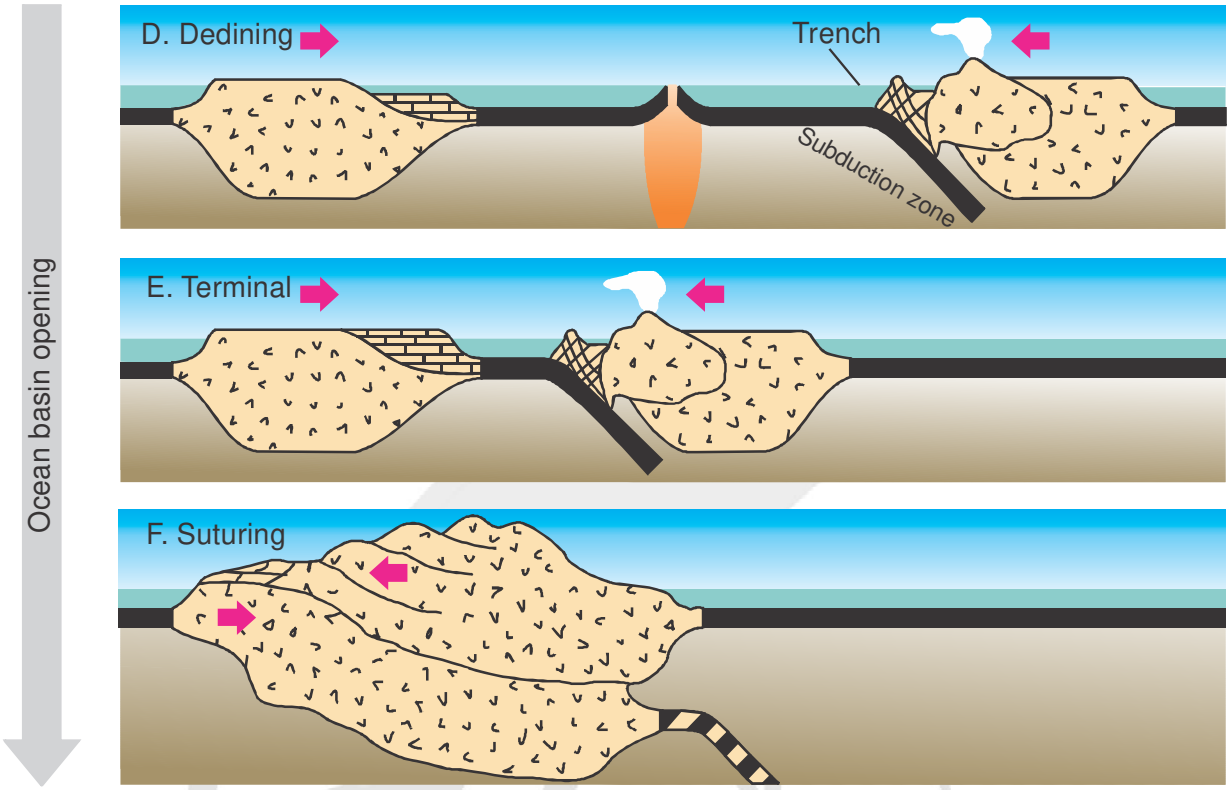



**Figure.4 : Simplified model of the Wilson cycle, showing the formation and closing of an ocean basin.**

# CSIR-UGC (NET) Earth Sciences

## Model Solved Paper

**Duration : 180 minutes** **Maximum Marks : 200**

**Read the following instructions carefully.**

The question paper is divided in three parts :

**Part 'A' :** The candidates shall be required to answer 15 questions. Each question shall be of two marks. The total marks allocated to this section shall be 30 out of 200.

**Part 'B' :** A candidate shall be required to answer 35 questions. Each question shall be of two marks. The total marks allocated to this section shall be 70 out of 200.

**Part 'C' :** A candidate shall be required to answer 25 questions. Each question shall be of four marks. The total marks allocated to this section shall be 100 out of 200.

» There will be negative marking for PART-A and PART-B @ 25% marks and for PART-C @ 33% marks for each wrong answer.

Eduncle.com

## PART- 'A'

**1.** A two digit number is six times the sum of its digits. If that number is represented as ab, then what will be the value of $a^b$?

(A) 625 (B) 1024
(C) 256 (D) 150

**2.** A gardener was asked to plant flowers in a row containing equal number of plants. He tried to plant 6, 8, 10 and 12 in each row, but 5 plants left in each case but when he planted 13 in a row, no plant was left. Find the least number of plants with him.

(A) 120 (B) 125
(C) 845 (D) 245

**3.** The average of five consecutive odd numbers is 47. What is the product of first and fourth number?

(A) 1940 (B) 2008
(C) 2021 (D) 2107

**4.** The boys and girls in a collegiate school are in the ratio 3 : 2. If 20% of the boys and 25% of the girls are adults, then what is the percentage of students who are minor?

(A) 78% (B) 58%
(C) 88% (D) 68%

**5.** A reduction of 10% in the price of rice enables a person to obtain 22 kg more for Rs.250. What is the original price of rice per kilogram?

(A) Rs.1.35 (B) Rs.1.50
(C) Rs.1.20 (D) Rs.1.24

**6.** The salary of Nitin increases every year in April by 15%. If his salary in July 2007 was Rs.20000, what was his salary in September 2009?

(A) Rs.26540 (B) Rs.26450
(C) Rs.24650 (D) Rs.25640

**7.** If the rate of interest be 4% per annum for the first year, 5% per annum for second year and 6% per annum for a third year, then what will be the compound interest of Rs.10000 for 3 years?

(A) Rs.1650.80 (B) Rs.1575.20
(C) Rs.1765.20 (D) Rs.2000

**8.** Two alloys containing copper and iron in the ratio 5 : 8 and 5 : 3 are melted in equal quantities. What is the ratio of iron and copper in the resulting mixture?

(A) 103 : 105 (B) 15 : 24
(C) 105 : 103 (D) 24 : 15

**9.** Sanjay bought 40 kilograms of wheat at Rs.12.50 per kilogram and 25 kilograms at Rs.15.10 per kilogram. He mixed them together. At what rate should he sell the mixture to earn 10% profit?

(A) Rs.13.50 (B) Rs.14.85

(C) Rs.14.75 (D) Rs.13.75

**10.** A float is drifting in a river, 10 m downstream of a boat that can be rowed at a speed of 10 m minute in still water. If the boat is rowed downstream, the time taken to catch up with the float

(A) will be 1 minute

(B) will be more than 1 minute

(C) will be less than 1 minute

(D) can be determined only if the speed of the river is known

**11.** Ankur, Bindu and Chandu completed a piece of work costing Rs.1800. Ankur worked for 6 days, Bindu for 4 days and Chandu for 9 days. If their daily wages are in the ratio 5 : 6 : 4, how much amount will be received by Amit?

(A) Rs.800 (B) Rs.600

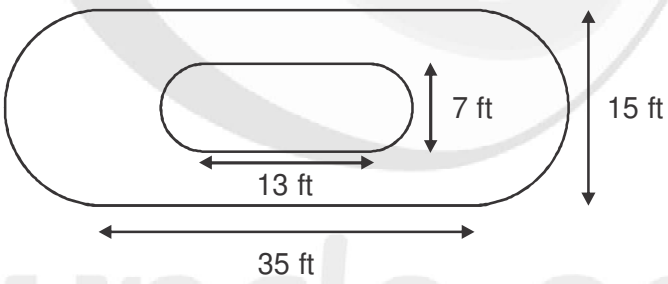
(C) Rs.900 (D) Rs.750

**12.** Mamta rolls an ordinary six-sided die repeatedly, keeping track of each number as she rolls, and stopping as soon as any number is rolled for the fifth time. If Mamta stops after her ninth roll, and the sum of these numbers she has rolled is 20, then how many combinations of numbers could she have rolled?

(A) 10 (B) 12

(C) 14 (D) 15

**13.** There is a botanical garden near your pond with a walkway around it. The figure shows the dimensions of the pond and the walkway. Find the area of the walkway.




(A) 525 $ft^2$ (B) 455 $ft^2$

(C) 91 $ft^2$ (D) 662.5 $ft^2$

**14.** It requires 12 litres of paint to paint the 6 sides of a cube with dimensions 2 m × 2 m × 2 m. The number of litres of paint required to paint the outside of a rectangular box with dimensions 4 m × 1 m × 8 m is

(A) 40 (B) 44

(C) 45 (D) 47

**15.** If the height of a pole is $2\sqrt{3}$ meters and the length of its shadow is 2 meters, find the angle of elevation of the sun.

(A) 45° (B) 60°
(C) 30° (D) 90°

## PART- 'B'

**16.** Which of the following pairs of garnets does not show solid solution?

(A) Pyrope - pyroxene (B) Almandine - Pyrope
(C) Almandine - Spessartite (D) Grossularite - andradite

**17.** To measure accurately the retardation of an anisotropic mineral, the accessory used is

(A) Gypsum plate (B) Berek compensator
(C) Quartz wedge (D) Optical goniometer

**18.** Consider the following minerals:

1. Olivine 2. Pyrrhotite
3. Chromite

The correct paragenetic sequence of these minerals in an early magnetic deposit is

(A) 1,2,3 (B) 1,3,2
(C) 3,2,1 (D) 2,3,1

**19.** Sulphide mineralization in Delhi Supergroup of rocks is localized along the

(A) Primary stratification plane (B) Shear zone
(C) NE-SW tectonic lineament (D) Axial trace of third generation of folds

**20.** Oxidation of Pb-Zn-Pyrite deposit will result in the

(A) Formation of placer deposit of pyrite
(B) Liberation of metals like Pb, Zn and Fe
(C) Formation of residual deposit of Zincite
(D) Formation of deposit containing sphlarite and galena

**21.** A heavy mineral assemblage of rounded grains of tourmaline, zircon and rutile suggests a provenance consisting of

(A) Pegmatites (B) Acid igneous rocks
(C) Basic igneous rocks (D) Reworked sedimentary rocks

**22.** The presence of omphacite and pyrope in metamorphic rocks indicates this the rocks were formed under.

(A) Low P and Low T (B) Low P and High T
(C) High P and High T (D) High P and Low T

**23.** The assemblage produced by the medium grade regional metamorphism of basic rock is
(A) Garnet, anorthite and hornblend
(B) Hornblend and plagioclase
(C) Garnet, mica, quartz, sodic plagioclase
(D) Sillimanite, garnet, quartz, mica, sodic plagioclase

**24.** Which one of the following evidences supports a metamorphic origin of granite?
(A) Chilled and sharp contacts of granite
(B) Apophysis of granite in the adjacent rocks
(C) Basic front and graded contact of granite
(D) Xenoliths of limestone in granite

**25.** The phenomenon that strata characterized by similar fossils occupy corresponding positions in different stratigraphic sections, is known as
(A) Correlation (B) Taxonomy
(C) Homotaxis (D) Heredity

**26.** Two gastropode genera Turritela and certhium can be distinguished from each other on the basis of
(A) Spiral angle
(B) Shape of the aperture
(C) Surface ornamentation
(D) Presence and/or absence of columella

**27.** Among the Siwalik mammals which one of the following does not belong to the group?
(A) Sus (B) Rhinoceros
(C) Giraffe (D) Dinotherium

**28.** The most common types of twins encountered in nature are
(A) Contact twin (B) Penetration twin
(C) Growth twin (D) Polysynthetic twin

**29.** Twinning that originates right from the time of crystallizations is termed as
(A) Paragenetic (B) Metagenetic
(C) Diagenetic (D) Polygenetic

**30.** The maximum number of space lattice is found in
(A) Orthorhombic system (B) Cubic system
(C) Hexagonal system (D) Tetragonal system

**31.** Which of the following exhibit pyroelectricity?
(A) Hemihedral crystals (B) Tetrohedral crystals
(C) Holohedral crystals (D) None of the above

**32.** Stylolites are formed due to
(A) Pressure, solution and temperature effects
(B) Pressure and solution effects
(C) Pressure effects only
(D) Solution effects only

**33.** Marine manganese nodules are formed in which of the following ways ?
(A) Deposition of seas into the ocean bottom
(B) Deposition by currents form various sources
(C) Insitu precipitation from the oceanic sediments of various types
(D) A combination of all the above

**34.** Oomphcite and garnet are the chief constituents of
(A) Anorthosites (B) Granulites
(C) Eclogites (D) Leptynites

**35.** The metamorphic facies which is characteristic of low geothermal gradients and found associated with geosynclines is referred as
(A) Blueschist facies (B) Glaucophane schist facies
(C) Eclogite facies (D) Sanidinite facies

**36.** Development of foliation in a metamorphic rock is mainly a function of
(A) Stress and temperature
(B) Lithostatic pressure and temperature
(C) Temperature and chemically active fluid
(D) Chemically active fluids and stress

**37.** That stromatolite is not a product of purely physical processes is best established by its
(A) Virtual restriction to carbonate rocks
(B) Preserved organic skeletal structure
(C) Convex- upward laminations, locally exceeding angle of repose
(D) Widespread development in Precambrian sequences

**38.** Shelf storm sands are distinguished from turbidites by
(A) Interlayering of sand and mud
(B) Wave ripple and wave ripple lamination
(C) Erosive base with diffusive top
(D) Sole marks

**39.** Which of the following are the consequences of diagenetic changes in mudrocks in the depth range of 2000-3700 m?
(A) Decrease in smectite cement (B) Increase in illite cement
(C) Decrease in calcitic cement (D) Increase in fine quartz/chert content

**40.** Benioff-zones are associated with
(A) Andesitic volcanism
(B) Calc- alkaline plutonism
(C) Calc - alkaline plutonism/volcanism
(D) Rhyolitic volcanism

**41.** The most obvious evidence for continent - reassembly is
(A) Morphological similarities of coastlines
(B) Glacial deposits distribution
(C) Palaeomagnetic data
(D) Sea floor spreading

**42.** A segment of the earth's crust exhibiting similar geological and geophysical properties is called
(A) Shield (B) Platform
(C) Orogen (D) Crustal type

**43.** The boundary between basalts of oceanic crust with their Island arcs and andesitic - Dacite - Rhyolite Volcannic or circum - Pacific belt is
(A) Benioff zone (B) Ring of fire
(C) Andesite line (D) Steinmann's trinity

**44.** In which of the following rocks mica is absent?
(A) Garnet - sillimanite graphite gneiss
(B) Garnet - sillimanite mica schist
(C) Peridotites
(D) None of the above

**45.** Which of the following is not a texture?
(A) Crystalloblastic (B) Diablastic
(C) Xenoblastic (D) Cataclastic

**46.** In the Digboi oilfields, the oil is obtained from
(A) Tippam formation (B) Barail formation
(C) Surma formation (D) Sylhet formation

**47.** Most of the manganese deposits in India are obtained from
(A) Sausar series (B) Sakoli series
(C) Kolhan series (D) Rialo series

**48.** Which of the following is freshwater formation?
(A) Barakar (B) Raniganj
(C) Jabalpur (D) Karharbari

**49.** Folds whose profiles are essentially semi- circular are termed as

(A) Similar fold (B) Parallel fold

(C) Cylindrical fold (D) Non- cylindrical fold

**50.** Sideronitic texture is a feature pertaining to

(A) Immiscible liquid segregation (B) Magmatic injection

(C) Early gravitative segregation (D) Late magmatic segregation

## PART- 'C'

**51.** Fault are generated by

(1) Extension (2) Shear

(3) Compression (4) Torsion

(A) 1 only (B) 1, 2 and 3 only

(C) 1 and 3 only (D) 3 and 4 only

**52.** If the rake of the net slip of a fault is 90', the fault may be a

(A) Strike - slip fault (B) Diagonal slip fault

(C) Dip- slip fault (D) Tear fault

**53.** Hade of a fault is

(A) 90º + dip (B) Plunge + Rake

(C) 90º – dip (D) Plunge + dip

**54.** In which type of fault the stratigraphic throw is measurable in many thousands of feet,

(A) Over thrust (B) Gravity faults

(C) Under thrust (D) Slip faults

**55.** In general, the probability of flooding decreases when there is an increase in the amount of

(A) Precipitation (B) Infiltration

(C) Runoff (D) Snow melt

**56.** At larger degress of undercooling, the nucleation rate will be high and the growth rate also high. This will result in many crystals all growing rapidly, but because there are so many crystals, they will run into each other before they have time to grow and the resulting texture will be a fine grained texture. If the size of the grains are so small that crystals cannot be distinguished with a handlens, the texture is said to be

(A) Phaneratic (B) Aphanitic

(C) Holohyaline texture (D) None of the above

**57.** Which of the following conditions may indicate an El Nino?

(A) Sea surface warms, trade winds strengthen

(B) Sea surface warms, trade winds weaken

(C) Sea surface cools, trade winds strengthen

(D) Sea surface cools, trade winds weaken

**58.** Regional metamorphism of limestone forms

(A) Schist (B) Phyllite

(C) Skarns (D) None of the above

**59.** Consider the following

1. Recumbent fold 2. Thrust fault

3. Net slip greater than a mile 4. Active hanging wall

Of the above, characteristics true for nappes are

(A) 1 only (B) 1,3

(C) 1,2,4 (D) 1,2,3,4

**60.** A reclined folds is one in which

(A) The beds are sheared perpendicular to the strike of the beds

(B) The beds are sheared parallel to the strike of the beds

(C) The anticlines and synclines dip towards the top and bottom

(D) None of the above

**61.** Which of the following are the folds with parallel arrangement of limbs?

(A) Isoclinal fold (B) Inverted folds

(C) Reclined fold (D) Symmetrical folds

**62.** In 'Flexures' the interlimb angle lies between

(A) 180º – 120º (B) 120º – 70º

(C) 70º – 30º (D) 30º – 0º

**63.** Food risk refers to :

(A) The chance of a flood occurring

(B) The number of people and properties exposed to floodwaters if a flood occurs

(C) The vulnerability of people and properties that are exposed to floodwater

(D) All of the above

**64.** Of the freshwater on Earth that is not trapped in snow peaks or glaciers, most of it (95%) is trapped in

(A) Lakes (B) Rivers

(C) Aquifers (D) Dams

**65.** Thunder is the sound of

(A) Clouds banging together (B) Lightning heating the air

(C) Earthquakes (D) Hail stones banging together

**66.** The inter- atomic linkage that is responsible for the coherence of inert gases when they are condensed to solids at low temperatures is

(A) Ionic bond (B) Covalent bonds

(C) Coordinate covalent bond (D) Vander waal's bond

**67.** Which of the following is not an enantiomorphic form?

(A) Pedion (B) Tetraoid

(C) Trapezohedron (D) Hexahedron

**68.** Folds with variable axial surfaces.

(A) Conjugate fold (B) Fan fold

(C) Cross fold (D) Polyclinical folds

**69.** The interlimb angles of fold give an inclination of the

(A) Genesis of folds (B) Morphology of folds

(C) Intensity of deformation (D) Type of deformation

**70.** The mineralization at Zawar as sheeted zones, veins, stringers and dissemination, forming lenticular bodies arranged in an enechelon pattern, restricted solely within the dolomite horizon. The form of the ore bodies may therefore be describes as

(A) Stratiform (B) Bedded

(C) Strata- bound (D) Tabular

**71.** In the future, which of the following is expected to increase the risk of flooding?

(A) Population growth (B) Urbanisation

(C) Climate change (D) All of the above

**72.** The Earth's crust is thickest at

(A) New Delhi (B) Dhaka

(C) Islamabad (D) Kathmandu

**73.** The Mohr- Boundary between the crust and the mantle discovered form the difference in the:

(A) Density (B) Gravity

(C) Velocities of seismic waves (D) None of these

**74.** Which of the following is called a large mass of igneous rock in Earth's crust that, if exposed at the surface, covers an area of at least 100 $km^2$?

(A) A volcano (B) A transform boundary

(C) a batholith (D) a fault line

**75.** Topographic maps usually illustrate elevation using contour lines (lines connecting points of equal elevation). Consider for example, this contour map. It represents a region of high relief along the continental divide near Estes Park, Colorado. What is the contour interval (the distance between adjacent contour lines)?

(A) 1,000 meters (B) 5 meters

(C) 10 meters (D) 50 meters

# ANSWER KEYS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| A | C | D | A | D | B | B | C | B | A |
| **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| B | A | D | B | B | D | B | C | B | B |
| **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** |
| D | C | B | C | C | A | D | B | A | A |
| **31** | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** |
| B | B | C | C | D | D | A | A | A | C |
| **41** | **42** | **43** | **44** | **45** | **46** | **47** | **48** | **49** | **50** |
| A | D | C | D | D | A | A | A | C | B |
| **51** | **52** | **53** | **54** | **55** | **56** | **57** | **58** | **59** | **60** |
| B | B | B | A | B | A | B | C | D | A |
| **61** | **62** | **63** | **64** | **65** | **66** | **67** | **68** | **69** | **70** |
| A | A | D | C | B | D | D | D | C | C |
| **71** | **72** | **73** | **74** | **75** | | | | | |
| D | D | B | D | A | | | | | |

# SOLUTIONS

## PART- 'A'

**1.** (A) According to the question,

10a + b = 6(a + b); where a represent ten's place and b unit's place.

Or, 10a + b = 6a + 6b

Or, 4a = 5b. Hence, a/b = 5/4.

This shows that ratio of ten's place digit to unit's place digit is 5 : 4.

So, the number is 54.

Therefore, $a^b = 5^4 = 625$.

The correct answer is (A).

**2.** (C) Minimum number of plants with gardener = L.C.M. of (6, 8, 10, 12) + 5 = 120 + 5 = 125.

This number will be repeated at the interval of L.C.M.

Hence the next number will be 125 + 120 = 245 and next number will be 245 + 120 = 365 and so on.

Least number of plants = 120 × 7 + 5 = 845, which is divisible by 13.

The correct answer is (C).

**3.** (D) Let the number be x, x + 2, x + 4, x + 6 and x + 8.

According to the question, $\frac{x+x+2+x+4+x+6+x+8}{5} = 47$

$5x + 20 = 235$

$x = \frac{215}{5} = 43$

First number = 43 and fourth number = 43 + 6 = 49.

So, product of first and fourth numbers = 43 × 49 = 2107.

The correct answer is (D).

**4.** (A) Let the boys be 3x and girls 2x.

Number of minors = 80% of 3x + 75% of 2x = $\frac{80}{100}\times 3x + \frac{75}{100}\times 2x = \frac{24x+15x}{10} = \frac{39x}{10}$

Hence, required percentage = $\frac{39x}{10}\times\frac{1}{5x}$ × 100 = 78%.

The correct answer is (A).

**5.** (D) Reduction in 10% corresponds to 22 kg.

∴ 10% corresponds to 22 kilograms.

∴ 100% corresponds to 220 kilograms.

Hence, at new price he can buy 220 kilograms.

Thus, at old price he can buy = 220 – 22 = 198 kilogram

Hence, original price = $\frac{250}{198}$ = Rs.1.24 per kilogram.

The correct answer is (D).

**6.** (B) According to question,

During the given period of July 2007 to September 2009, the salary of Nitin increased twice.

Thus, the overall increase in the salary = $15 \times 15 + \frac{15 \times 15}{100} = 32.25\%$

Hence, the salary in September 2009 = $\frac{20000 \times 132.25}{100}$ = Rs.26450

The correct answer is (B).

**7.** (B) Amount = Rs. $\left[10000 \times \left(1+\frac{4}{100}\right) \times \left(1+\frac{5}{100}\right) \times \left(1+\frac{6}{100}\right)\right]$

$= \text{Rs.}\left[10000 \times \frac{26}{25} \times \frac{21}{20} \times \frac{53}{50}\right] = \text{Rs.}\frac{57876}{5} = \text{Rs.}11575.20$

Compound interest = Rs.(11575.20 – 10000) = Rs.1575.20.

The correct answer is (B).

**8.** (C) Assume the quantity of one alloy = x

$$\frac{\text{Copper}}{\text{Iron}} = \frac{x \times \frac{5}{13} + x \times \frac{5}{8}}{x \times \frac{8}{13} + x \times \frac{3}{8}} = \frac{\frac{5x}{13} + \frac{5x}{8}}{\frac{8x}{13} + \frac{3x}{8}} = \frac{105}{103}.$$

The correct answer is C.

**9.** (B) Cost price of wheat = (40 × 12.50) + (25 × 15.10) = Rs.877.50

Selling price = $877.50 \times \frac{110}{100}$ = Rs.965.25

$\therefore$ Price per kilogram = $\frac{965.25}{65}$ = Rs.14.85.

The correct answer is (B).

**10.** (A) The float is 10 m downstream of the boat.

Since there is no external force on the float, then speed of the float = speed of the river.

As we know that, speed of the boat = rowing speed of the boat + speed of the river.

Distance to be covered by the boat = 10 m.

Relative speed of the boat = speed of the boat – speed of the float.

= (rowing speed of the boat + speed of the river) – speed of the river

= rowing speed of the boat = 10 m/minute.

Hence, time by the boat to catch up with the float

$$= \frac{\text{Distance to be covered by the boat}}{\text{Relative speed of the boat}} = \frac{10}{10} = 1 \text{ minute.}$$

The correct answer is (A).

**11.** (B) Ratio of wages of Ankur, Bindu and Chandu =

$(6 \times 5) : (4 : 6) : (9 : 4) = 30 : 24 : 36 = 5 : 4 : 6$

Ankur's share = Rs. $\left(1800 \times \frac{5}{15}\right)$ = Rs.600. The correct answer is (B).

**12.** (A) Consider number as: x = 1, then a + b + c + d = 15

Combinations are : (2, 2, 5, 6)

(2, 3, 4, 6)

(2, 3, 5, 5)

(3, 3, 3, 6)

(3, 3, 4, 5)

(4, 4, 4, 3)

(4, 4, 2, 5)

Consider number as : x = 2, then a + b + c + d = 10 (1, 1, 3, 5)

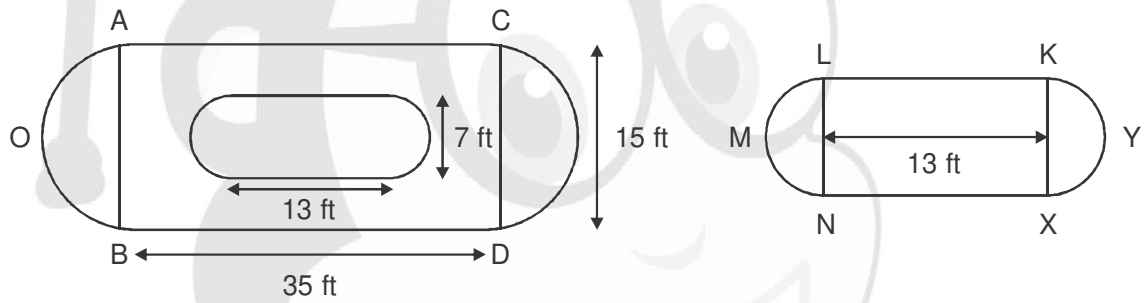
(1, 1, 4, 4)

(3, 3, 3, 1)

Possible number of combinations is 10.

The correct answer is (A).

**13.** (D)




Total area of botanical garden is = $\frac{\pi(AB/2)^2}{2} + 15 \times 35 + \frac{\pi(CD/2)^2}{2} = \pi\left(\frac{15}{2}\right)^2$ + 525 = 176.78 + 525 ≅ 701 ft²

The area of the walkway = total area of garden – area of pond = 701 – 38.5 = 662.5 ft².

The correct answer is (D).

**14.** (B) Total surface area of cube = 6(2 × 2) m² = 24 m²

Total surface area of rectangular box = [2(8 × 1) + 2(4 × 1) + 2(8 × 4)]m² = [16 + 8 + 64]m² = 88 m²

If 24 m² needs 12 litre of paint, i.e. 1 litre for every 2 m², 88 m² needs 44 litre of paint.

The correct answer is (B)

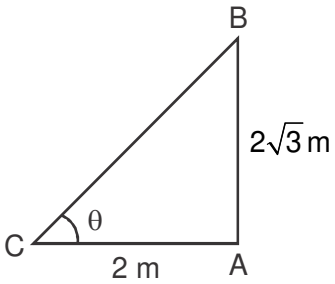
**15.** (B) Let AB be the pole and AC be its shadow.

Then, ∠ACB = θ.

Then, AB = $2\sqrt{3}$ m, AC = 2m,

$\tan\theta = \frac{AB}{AC} = \frac{2\sqrt{3}}{2} = \sqrt{3}$

So, θ = 60°.



## PART- 'B'

**16.** (D) Only garnets (d) in the above options do not show solid solution.

**17.** (B) To measure accurately the retardation of an anisotropic mineral, the accessory used is berek compensator.

**18.** (C) The correct paragenetic sequence of these minerals in an early magnetic deposit is :
1. Chromite 2. Pyrrhotite 3. Olivine

**19.** (B) The mineralization is mainly localized in mainly in the shear zone.

**20.** (B) Oxidation of Pb - Zn - Pyrite deposite will result in the Liberation of metals like Pb, Zn and Fe.

**21.** (D) A heavy mineral assemblage of rounded grains of tourmaline, zircon and rutile suggests a provenance consisting of reworked sedimentary rocks.

**22.** (C) High pressure and high temperature and it is mainly granulite facies.

**23.** (B) These minerals are indicative of Amphibolite facies and the protolithic of this rock is mainly basic rock.

**24.** (C) Basic front and graded contact of granite.

**25.** (C) This is mainly called homotaxis where the strata characterized by similar fossils occupy corresponding positions in different stratigraphic sections.

**26.** (A) The spiral angles of these two gastropods are really different. Spiral angle of Turritela is smaller than the spiral angle of the Cerithium.

**27.** (D) Dinotherium

**28.** (B) Penetration twin

**29.** (A) When twinning starts from the crystallisation it is mainly called Paragenetic.

**30.** (A) Orthorhombic system

**31.** (B) Tetrohedral crystal mainly shows pyroelectrocity among the other crystals.

**32.** (B) Stylolites are mainly formed due to the precipitation due to the pressure and solution.

**33.** (C) Insitu precipitation is the main process for the formation of the marine manganese.

**34.** (C) Eclogites are the main rock of the granulite facies.

**35.** (D) Sanidinite facies is characteristic of low geothermal gradient.

**36.** (D) Stress and chemical fluid or magmatic fluid both are important.

**37.** (A) Restriction to carbonate rock indicates that stromatolite is not the result of any pure physical process.

**38.** (A) Shelf storm sands are mainly formed by sand and turbidite has some different zones of interlayering sand and mud.

**39.** (A) Smectite cement percentage is the most indicative for the above mentioned depth range.

**40.** (C) Beni off zone means convergent and subduction zone where calc-alkaline volcanism takes place.

**41.** (A) The most striking evidence which drives the scientists for involvement to interpret the theory is morphogical similarities of the coastlines.

**42.** (D) Crust mainly shows similar geological and geophysical properties.

**43.** (C) The line mainly contains andesite rock.

**44.** (D) Here all the rocks have mica.

**45.** (D) Cataclastic is a structural term which describes the rocks formed due to brittle deformation.

**46.** (A) Tippam formation is the main reservoir for the Digboi oil field.

**47.** (A) Mansar formation has significant epigenetic and syngenetic manganese deposits.

**48.** (A) Barakar is fresh water formation among other formations of Gondwana.

**49.** (C) In that case the fold is mainly semi circular fold.

**50.** (B) This texture is formed when magmatic injection takes place.

## PART- 'C'

**51.** (B) Faults are generated by extension & compression.
Under the influence of stresses developing from within the Earth, the rock masses adjust themselves either by bending when they lie deep below the surface (in zone of flowage) or by fracturing with or without any accompanying displacement, in the upper depths (the zone of fracturing). Fracturing is favored when the stresses are shearing in nature and the rocks are brittle in character. It normally occurs when the shearing strength of the rocks is overcome by the operating stresses.

**52.** (B) If the rake of the net slip of a fault is 90', the fault may be a Dip- slip fault.

**53.** (B) The hade of the fault is the angle which the fault makes with the vertical. In other words it is the complimentary to dip angle. Hade of a fault is 90º – dip

**54.** (A) The Himalayan Mountains in the Indian subcontinent present numerous examples of thrust faults developed all along its extension from northwest to southeast. In the outer Himalayas, the **MAIN BOUNDARY FAULT** is the most important example of thrust faults, which extends from Punjab to Assam along which the older Murree formations have been thrust up and overlie the younger Shiwalik formations for several hundred kilometers. When the footwall stays in position and the hanging wall is transported, the fault is called an over thrust. If the foot wall moves instead of the hanging wall, The thrust is called an underthrust. In over thrust fault, the stratigraphic throw is measurable in many thousands of feet.

**55.** (B) The other choices have to do with an increase in water amount. Infiltration has to do with water being placed into the ground; not on the surface.

**56.** (A) Phaneratic texture is mainly formed due to the undercooling of the crystallisation.

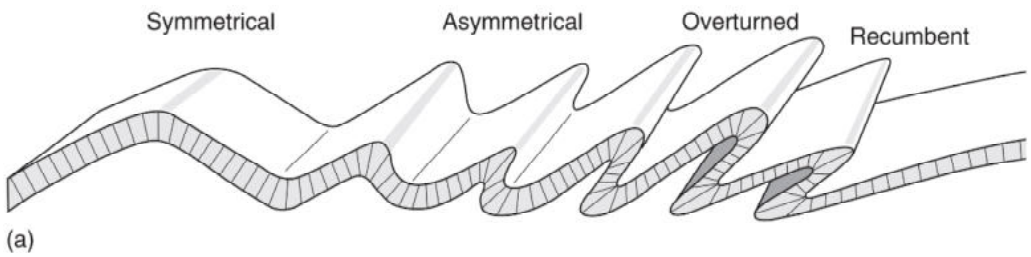
**57.** (B) The warm water of El Nino (ENSO) encompass the central Pacific region. Normally, a warm pool of ocean water builds up in the western equatorial Pacific Ocean. When air pressure patterns weaken, though, the trade winds decreases or even reverse direction. This causes the warmer water moneastward.

**58.** (C) Skarns are product of the metamorphism of limestone.

**59.** (D) All are the characteristics of the Nappe. Nappes are of two types, one is thrust nappe and another is fold nappe.

**60.** (A) In the case of the reclined bed the pitch of the fold axis on the axial plane is 85º to 90º

**61.** (A) Isoclinal fold are the folds with parallel arrangement of limbs.
These are group of folds in which all the axial planes are essentially parallel, meaning that all the component limbs are dipping at equal amounts. They may be made up of series of anticlines and synclines.



(a)

**62.** (A) In 'Flexures' the interlimb angle lies between 180º – 120º

**Flexural Folding :** It is that process of folding in which the competent or stronger rocks are thrown into folds due to their against each other under the influence of lateral compression.

**63.** (D) Flood risk includes both the chance (or probability) of a flood occurring, and the consequences if a flood occurs. The consequences of a flood are in turn affected by the number of people and properties exposed to floodwaters for a flood of a particular size, and the vulnerability of those people and properties. For example, a river might burst its banks regularly, but if this flooding occurs in an isolated area where there are no people or infrastructure, then the risk is low. Similarly, a river might flood very rarely, but if many people and properties are located near this river and they live in dwellings that are vulnerable to water damage, then the flood risk will be greater.

**64.** (C) The oceans hold 98% of all water on earth. Freshwater only makes up 2%. Of that 2%, 90% of it is trapped in ice and snow, which is rapidly melting due to global warming. Of the freshwater left, the majority is found in groundwater, with the remaining 3% of freshwater found in lakes, river and streams. Of the total amount of water on Earth only 0.01% is located in the lakes rivers, and streams.

**65.** (B) A lightning bolt heats the nearby air very hot ; thunder is the sound of the surrounding cold air masses banging back together.

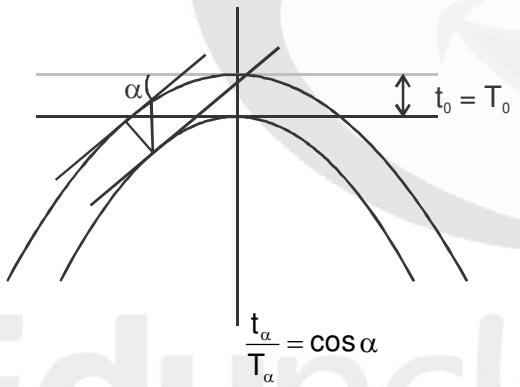
**66.** (D) The inter atomic linkage is actually vander waal's bond.

**67.** (D) Either of a pair of objects related to each other as the right hand is to the left, that is , as mirror images that cannot be reoriented so as to appear identical. An object that has a plane of symmetry cannot be an enantiomorph because the object and its mirror image are identical.

**68.** (D) Folds with variable axial surfaces are known as Polyclinical folds.

**69.** (C) The interlimb angles of fold give an inclination of the Morphology of folds.

Morphological classification of folds




[$t_0$ = orthogonal thickness
$T_0$ = Axial plane thickness
(Thickness parallel to the axial plane]

According to ramsay, the folds have been classified into three classes :

1. Class -1 (Converging dip isogone)
2. Class -2 fold
3. Class -3 fold

**70.** (C) Strata bound deposits are those which are restricted within the strata.

**71.** (D) In the future, climate change is likely to result in an increased chance of flash floods and coastal inundation. Australia's growing population and urbanisation are likely to place increased pressure on our waterways and to increase the chance of flooding in cities and the number of properties and people exposed to floodwaters.

**72.** (D) Kathmandu is situated in Nepal which is in Himalayan mountain region so it is convergent plate boundary, so it will have the highest thickness of the earth crust.

**73.** (B) Gravity

**74.** (D) a fault line

**75.** (A) 1,000 meters



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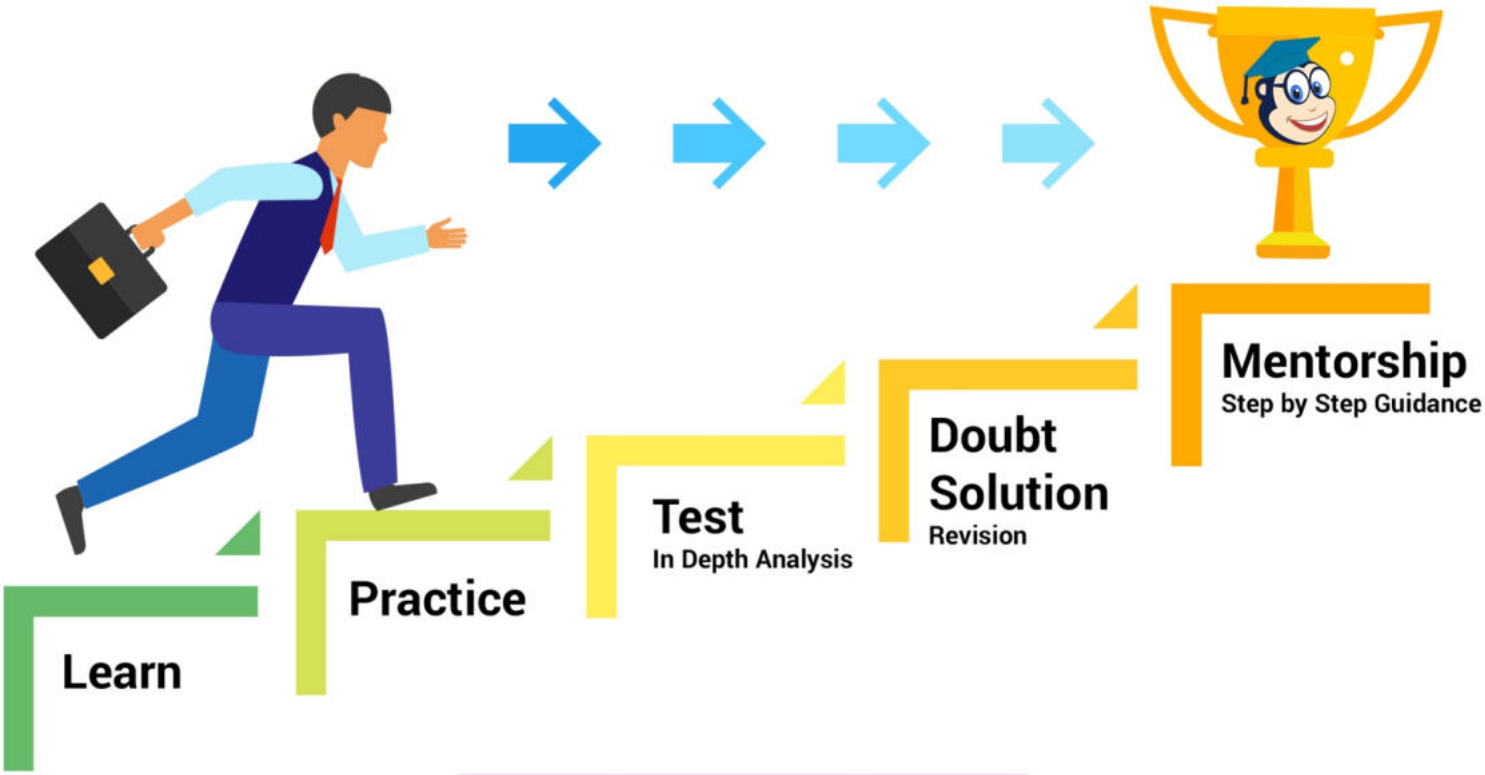


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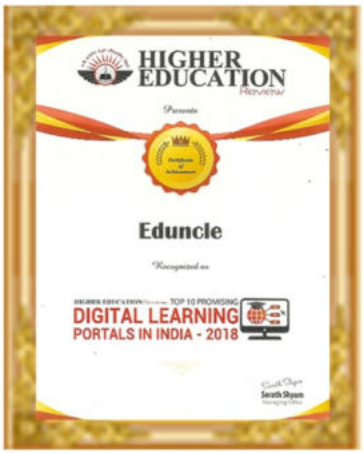

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